# PHYSICAL ACTIVITY AND FITNESS MEASURES IN NEW ZEALAND: A STUDY OF VALIDATION AND CORRELATION WITH CARDIOVASCULAR RISK FACTORS

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# ABSTRACT

The primary aim of the study was to validate the short and long form of the recently-created NZ physical activity questionnaires (NZPAQ-SF and NZPAQ-LF, respectively) in a multi-ethnic sample in Auckland. An international physical activity questionnaire (IPAQ-long) was also validated and compared to the NZ instruments. Objective PA measures were used to create a NZ compendium of PA intensities, providing baseline data for culturally-specific PAs. Secondary aims included an examination of the relationship between PA and CRF, and their associations with cross-sectional measures of cardiovascular (CV) risk factors.

The study sample consisted of 186 apparently healthy males (n=90) and females (n=96) aged 19-86 yrs, classified as European/Other (n=60), Māori (n=61), and Pacific (n=65). Heart rate monitoring (HRM) with individual calibration was used to objectively measure the duration, frequency, and intensity of at least moderate-intensity PAs performed over 3 consecutive days. Type of PA and the context in which it was performed was simultaneously recorded by participants on daily PA logs. Correlations between HRM and self-reported levels of brisk walking, moderate-intensity, vigorous-intensity, were poor for each questionnaire, and correlations were lower for Māori and Pacific ethnic groups than for European/Other. The NZPAQ-SF ($r=0.3$, $p<0.001$) and NZPAQ-LF ($r=0.3$, $p<0.001$) performed better than the IPAQ-long ($r=0.1$, $p=0.37$). The culturally-specific list of PA intensities showed strong correlation ($R^2=0.68$) to an internationally-accepted compendium of PA intensities, and provided baseline energy cost data for 13 PAs performed by Māori and Pacific people in NZ. CRF levels were primarily influenced by gender, ethnicity, obesity, and performing at least 15 min/day of vigorous-intensity PA, and showed stronger associations with fasting blood lipids and glucose, while PA was more strongly related to SBP and DBP.

The validated NZPAQs are acceptable for measuring population level PA prevalence in NZ adults, although accuracy is lower for Māori and Pacific people. However, the availability of a culturally-specific list of PA intensities could potentially increase the accuracy of self-reported PA by Māori and Pacific people. Results from this study highlight the importance of vigorous-intensity PA for CV health, and identifies NZ Pacific people as high risk in terms of PA, obesity, and CRF.

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| | |
|---|---|
| ACSM | American College of Sports Medicine |
| AEE | activity energy expenditure |
| API | Asian and Pacific Island people |
| BMI | body mass index |
| BMR | basal metabolic rate |
| BP | blood pressure |
| bpm | beats per minute |
| $CAL_{EE}$ | energy expenditure determined by calorimetry |
| CDC | Center for Disease Control |
| CHD | coronary heart disease |
| CI | confidence interval |
| $CO_2$ | carbon dioxide |
| CRF | cardiorespiratory fitness |
| CSA | Computer Science and Applications, Inc. |
| CV | cardiovascular |
| CVD | cardiovascular disease |
| DBP | diastolic blood pressure |
| DGPS | differential satellite global positioning system |
| DLW | doubly labeled water |
| $DLW_{EE}$ | energy expenditure determined by doubly labeled water |
| EE | energy expenditure |
| EPAQ2 | European Physical Activity Questionnaire (modified) |
| EPIC | European Prospective Investigation into Cancer and Nutrition |
| FWH | four-week histories |
| HDL | high density lipoprotein |
| HR(s) | heart rates |
| HRFlex | heart rate flex method |
| $HRFlex_{EE}$ | energy expenditure determined by heart rate flex method |
| (%)$HR_{max}$ | (percentage of) maximum heart rate |
| HRM | heart rate monitoring |

| | |
|---|---|
| $HRM_{EE}$ | energy expenditure determined by heart rate monitoring |
| $HR_{net}$ | net heart rate |
| (%)HRR | (percentage of) heart rate reserve |
| IPAQ-long | International Physical Activity Questionnaire – long Form |
| kcal(s) | kilocalorie(s) |
| kg | kilogram |
| L | litres |
| LDL | low density lipoprotein |
| ln | natural log |
| LTPA | leisure-time physical activity |
| MET(s) | metabolic equivalent(s) |
| min(s) | minute(s) |
| ml | millilitres |
| MOH | Ministry of Health |
| n | number |
| NCD | non-communicable diseases |
| NZ | New Zealand |
| NZHS | New Zealand Health Survey |
| NZPAQs | New Zealand Physical Activity Questionnaires |
| NZPAQ-LF | New Zealand Physical Activity Questionnaire – long form |
| NZPAQ-SF | New Zealand Physical Activity Questionnaire – short form |
| NZSPAS | New Zealand Sport and Physical Activity Questionnaire |
| $O_2$ | oxygen |
| PA | physical activity |
| PAJMG | Physical Activity Joint Monitoring Group |
| PA Log(s) | physical activity log(s) |
| PAL | physical activity level |
| PAQ(s) | physical activity questionnaire(s) |
| PAR | population attributable risk |
| PAR-Q | Physical Activity Readiness Questionnaire |
| PWC | physical work capacity |
| r | Spearman's correlation coefficient |
| $R^2$ | correlation coefficient squared |

| | |
|---|---|
| RHR | resting heart rate |
| RMR | resting metabolic rate |
| RPE | ratings of perceived exertion |
| rpm | revolutions per minute |
| SBP | systolic blood pressure |
| SD | standard deviation |
| SE | standard error |
| SeDS | Sedentary Death Syndrome |
| SEE | standard error of the estimate |
| SEM | standard error of the mean |
| SPARC | Sport and Recreation New Zealand |
| SSAAQ | Sub-Saharan Africa Activity Questionnaire |
| TC | total cholesterol |
| TEE | total energy expenditure |
| US | United States |
| $VO_2$ | oxygen consumption |
| $VO_{2max}$ | maximum oxygen consumption |
| WHO | World Health Organization |
| WPV | within-person variation |
| yrs | years |

# CHAPTER 1

# INTRODUCTION AND BACKGROUND

New Zealand (NZ) has the highest rates of cardiovascular disease (CVD) and coronary heart disease (CHD) mortality in the Asia-Pacific region.[1] The global significance of physical inactivity, its relationship to obesity and contribution to adverse health outcomes, is introduced in this chapter. The totality of physical activity (PA) is conceptualised by describing the dimensions and contexts of this behaviour, leading to the importance of accurately assessing PA in its entirety. This chapter also addresses pros and cons of physical activity questionnaires (PAQs) and the need for a valid instrument that enables comparisons within and between populations. In addition to providing a brief definition of cardiorespiratory fitness (CRF), a distinct yet closely related cardiovascular (CV) risk factor, associated health benefits and assessment techniques are also presented. Next, the economic impact of physical inactivity in NZ is reported, as well as the creation of two PAQs designed specifically for the NZ population. This chapter is concluded by stating the study aims, and explaining the contributions of this study to PA research in NZ.

## 1.1 PHYSICAL ACTIVITY

### 1.1.1 Physical Activity and Health

The crucial role of a physically active lifestyle for maintaining and improving physical, physiological, and psychological health is recognized internationally.[2,3] Regular participation in PA is associated with numerous health benefits essential for reducing risk of noncommunicable diseases and adverse health conditions, such as CVD, diabetes, some forms of cancer, hypertension and hypercholesterolemia.[4-12] Furthermore, PA results in energy expenditure (EE), which plays a fundamental role in reducing obesity rates, currently an epidemic of global concern.[13-17] Leading a sedentary or physically inactive lifestyle has been reported to be greater risk to health than cigarette smoking.[18] The economic burden associated with physical inactivity and obesity is high, affecting individuals and health care systems around the world.[19,20]

### 1.1.2 What is Physical Activity?

Physical activity is 'the voluntary movement produced by skeletal muscles that result in energy expenditure'. This broad definition was established by Caspersen et al.[21] in 1985, and serves as the standard definition, widely accepted by PA researchers.

Physical Activity Dimensions

The dimensions of PA include activity mode, frequency, duration, intensity, and context in which it is performed. These are essential for obtaining complete assessments of PA that are in line with current recommendations. The mode of PA refers to the specific activity being performed,[5] and frequency indicates how often PAs are performed in a defined period of time (i.e. past 7 days, past month, past year, etc).[16] Duration refers to the time period in which the PA is carried out, and is typically measured in minutes.[5] The intensity of a PA signifies the amount of physical exertion associated with a given PA, and is expressed either in kilocalories per minute ($kcals \cdot min^{-1}$) or metabolic equivalents (METs), which accounts for body weight.[22,23] One MET is the rate of oxygen ($O_2$) consumption of an average adult sitting quietly (3.5 ml $O_2 \cdot kg^{-1}$ $min^{-1}$).[24,25] PA intensity performed by individuals or populations of similar age, ability and fitness level is categorised in absolute terms as 'light' (<3 METs), 'moderate' (3-6 METs) or 'vigorous' (>6 METs). However, most physiological responses to exercise are dictated by the relative intensity,[26] and influenced by factors such as age, gender, weight, disability, and fitness level.[3,5,27] For example, intensity levels of two individuals running at the same pace could vary enormously, both subjectively and objectively. Person A, a regularly active individual who runs frequently, could perceive the activity as moderate-intensity, not requiring much physical effort. However, Person B, an older and less active individual, may have put forth maximum effort to maintain the running pace, and each individual's rating of perceived exertion would differ dramatically. An objective physiological measure, such as heart rate (HR), can indicate the actual intensity each individual was working at, relative to their age, fitness, and PA level.[27]

Physical Activity Contexts

PA context identifies the specific intention for which PA is performed, and is an important dimension of this lifestyle behaviour. PAs are carried out for a range of purposes, including sport and recreation, on the job, as a means of travel, and in and around the household. Until recently, PA research focused primarily on leisure-time physical activity (LTPA) and often overlooked other PA contexts and intensity, leading to substantial underestimates and misclassification of PA levels for many individuals.[6,8,28,29] For example, an individual may have a physically demanding occupation which limits the amount of PA performed outside of working hours. Similarly, the majority of women's activities occur in other contexts, such as child or family care in the household, activities on the job or as a means of transport.[30,31] It is essential for PAQs to capture information on all PA contexts to determine true PA levels. The dimensions of PA are described in further detail in Section 2.2.

### 1.1.3 Measurement of Physical Activity

Current PA recommendations advocate at least 30 minutes of moderate-intensity, endurance-type activity on most, preferably all, days of the week.[6] It is important to assess the proportion of populations meeting these current guidelines so that effective interventions can be implemented to target high-risk populations. Several subjective and objective methods of PA surveillance exist, but currently there is no internationally agreed assessment technique, so that surveillance remains challenging and problematical.[3,32-36]

Physical Activity Questionnaires

Ideally, PA assessments should be comparable within- and between- populations and countries. PAQs, although subjective in nature, remain the most feasible measurement instrument for epidemiological studies.[3,8,32,33,36-43] However, PAQs tend to sacrifice accuracy in exchange for practicality, as the expense, level of participant burden, and time required with gold standard and other objective techniques are not feasible in population studies.[41,42] Nonetheless, these instruments are currently the best available option and a plethora of PAQs exist. Researchers must determine which PAQ is most appropriate for the study sample and congruent with research goals.[44]

Prior to its use, the PAQ of choice must be validated by an objective measure in the specific population it is intended for, to ensure accurate assessments, as any conclusions related to its validity are limited to the population in which it was administered.[45,46] Ideally, PAQs should be validated by an objective, more precise assessment of PA.[29] Doubly-labeled water (DLW), a gold standard technique for PA, has demonstrated correlations with PAQs ranging from 0.57-0.79.[29] Although validity coefficients of at least 0.6 are desired, PAQs typically show limited validity (0.2 – 0.4),[16,47] despite extensive use over the last 40 years. However, moderate PAQ validity coefficients ranging from 0.3-0.5 are typically accepted relative to other direct or indirect measures of PA and EE.[29]

PAQs are difficult to validate for several reasons. The construction and wording of PAQs affects validity coefficients, as participants get bored or confused with long or complex instruments.[29] In addition to the inherent recall bias associated with self-report,[48] social desirability bias causes participants to provide socially-acceptable responses, overestimating time spent physically active and underestimating time spent inactive. Furthermore, terminology and concepts characteristic of PAQs are subject to interpretation bias,[8] which can also vary between cultures.[49] An appropriate validation technique is necessary, as many previously used methods (i.e. obesity, caloric intake, fitness, lung function, PA diaries, previously validated PAQs, etc) were unsuitable as they are not direct measures of PA.[22,46,50]

Objective Measures of Physical Activity

The gold standard methods (calorimetry and DLW) are not practical for PAQ validation on large-scale studies. Accelerometry and minute-by-minute heart rate monitoring (HRM), which have much lower respondent burden than calorimetry and DLW, are the preferred PAQ validation methods due to their capabilities of objectively measuring the frequency, duration, intensity, and EE of performed PAs, and lack of correlated error.[36] Accelerometers are small devices worn at the trunk and/or limbs that monitor the intensity of acceleration and deceleration of body mass, usually in the vertical plane.[32] Heart rate (HR) monitors detect and record individual's HR via electrodes in a transmitter belt worn around the chest, and display the reading, in beats per minute (bpm), on a receiver watch worn by the participant.

This study favoured the use of HRM with individual calibration over accelerometry for several reasons. Firstly, accelerometers are widely criticised for being incapable of quantifying EE for a wide range of PAs,[32,48,51,52] including light- and vigorous-intensity PAs, upper body activity, or activities where the body weight is partially supported, as in bicycling or rowing.[48,51-54] Accelerometers are also unable to detect increases in PA intensity (i.e. pushing or carrying loads, grade or velocity changes, or activities performed on soft surfaces),[38,48,51,52,55] and typically underestimate free-living EE.[56,57] The validity of accelerometer readings, which typically range from 0.21-0.53,[42] should be based on a variety of free-living activities, but accurate measures are not obtainable.[32,35,38,48,51-55,58] Furthermore, accelerometers are not waterproof, [52] and anthropometric measures affect instrument readings, making them unsuitable for large-scale studies.[59] Conversely, HRM provides researchers with accurate data on free-living PA and EE,[60,61] and has been validated against DLW and calorimetry with a correlation of 0.94.[62,63] HRM is superior to accelerometry as it provides both relative and absolute indices of PA intensity,[27,64] and higher correlations with PAQs.[36] HRM is well-accepted as a feasible, relatively inexpensive technique, easy to implement in epidemiological studies.[3,21,32,33,35,36,38,40,60,61,65-70]

## 1.2 CARDIORESPIRATORY FITNESS

CRF is a health-related component of physical fitness that refers to the ability of the circulatory and respiratory systems to supply oxygen ($O_2$) during prolonged bouts of PA[3,71] Higher fitness levels allow individuals to sustain higher intensity PAs for longer time periods, compared to their less fit counterparts.[25,65] Recent PA pattern over past weeks and months is the primary determinant of an individual's CRF level,[72] followed by genetics,[73] and other contributing factors such as age, gender, medical status, and selected health-related behaviours.[74]

### 1.2.1 Cardiorespiratory Fitness and Health

Previously, CRF levels have been used to validate PAQs, although CRF is not a direct measure of PA. Differentiation between CRF and PA is important, as both have major, yet distinct, cardioprotective roles.[75-78] Research shows an inverse dose-response relationship between CRF and morbidity and mortality rates for CHD,[23,40,75,79,80] CVD,[30,40,76,81-83] Type 2 diabetes,[84] the metabolic syndrome,[85-87] and premature death from all causes, which is independent of other major risk factors.[40,78,80,82,88,89] Unfit individuals have a 50% and 70% higher mortality rate compared to moderately-fit and high-fit individuals, respectively.[82] This finding is irrespective of body weight, as unfit, normal weight individuals have higher CVD and all-cause mortality rates than moderately-fit, obese individuals,[87] and EE levels in older adults.[76] Although these inverse associations are similar to those reported for PA, the relationships between CRF, health outcomes and mortality are consistently stronger.[72,76] CRF and a physical inactivity are therefore recognised as separate risk factors, and increases in both are currently recommended for primary and secondary CHD prevention.[78]

### 1.2.2 Assessment of Cardiorespiratory Fitness

The criterion measure of CRF is an individual's maximum capacity for oxygen consumption ($VO_{2max}$),[3] and is typically assessed by maximal exercise test performance on a cycle ergometer or treadmill.[40] The appropriateness of maximal exercise testing is limited by the burden and time requirements to both participants and testing staff, as well as risk to participants.[25,40] Estimating $VO_{2max}$ from submaximal exercise tests offers an alternative, more pragmatic approach to assessing CRF levels, which substantially reduces time requirements and participant risk.[25,40] However, the decision between maximal and submaximal exercise testing ultimately depends on several factors, including the purpose for exercise testing, the sample size and health status of participants, the research timeline and availability of funds.[25] CRF testing is discussed in further detail in Section 2.3.3.

### 1.2.3 Correlates of Cardiorespiratory Fitness

An individual's CRF level is largely determined by recent participant in PA,[72] as well as genetics.[73] Males and younger individuals[77] tend to have higher $VO_{2max}$ levels, compared to females and older adults.[25,74] After CRF assessments were performed on each participant in this study, multiple regression models were run to examine the relationships between predicted $VO_{2max}$ and CV risk factors, and identify the variables, other than age and gender and total PA, which determined individual $VO_{2max}$ levels. Independent variables in the models included ethnicity (European/Other, Māori, Pacific), gender, body mass index (BMI - normal weight, overweight, obese), and smoking. Additionally, it was important to distinguish between total daily duration of moderate- and vigorous-intensity PA, and compare the magnitude of associations with $VO_{2max}$.

## 1.3 PHYSICAL ACTIVITY LEVELS IN NEW ZEALAND

The high level of physical inactivity in NZ is a contributing factor to the world obesity epidemic. Two NZ population surveys, conducted between 1996-8, reported 34% and 39% of adults were physically inactive (<2.5 hours of participation in weekly LTPA), while an additional 10% and 15% of adults were classified as sedentary (no participation in LTPA in the last month).[5,10] Further, prevalence of overweight and obesity in NZ dramatically increased by 55% between 1989-1997,[6,10] and are projected to increase 70% by 2011.[26] In 1996, annual health care costs for obesity-related diseases and conditions were conservatively estimated at $135 million.[20] Improving PA levels is one aim of the NZ Health Strategy.[6]

### 1.3.1 Creation of New Zealand Physical Activity Questionnaires

In 2001, the Physical Activity Joint Monitoring Group (PAJMG) was established. The PAJMG's primary objective was to improve current measures of PA prevalence data in adults in NZ.[6] Two PAQs were created, a long form (NZPAQ-LF) and a short form (NZPAQ-SF). The NZPAQ-LF is essentially a 7-day PA diary, also referred to as the Main PA Table. This instrument was designed as the primary surveillance instrument, designed to be implemented into the next New Zealand Sport and Physical Activity Survey (NZSPAS), as it allows for assessment of trends and variations in the level and distribution of PA in the NZ population.[28] In addition to capturing PA in every dimension (mode, frequency, duration, intensity) and context (transportation, occupation, domestic work, organized sport, and informal leisure time and recreational pursuits), this instrument also enquires about resistance training, PAs performed at split intensities (consisting of both moderate- and vigorous-intensity levels), and time spent being inactive. The NZPAQ-SF was modified from an international PAQ (IPAQ-short) to reflect NZ culture and conditions, and to correlate with the NZPAQ-LF. This instrument measures the frequency, intensity, and duration of walking, moderate- and vigorous-intensity PA.[28]

Both New Zealand physical activity questionnaires (NZPAQs), designed for administration at the population level, required validation to ensure they measured what they intended to measure. Therefore, the validation sample size must be large enough to adequately represent the NZ population, and include individuals of both sexes, representing different demographic, ethnic or cultural groups over a wide range of PA levels.[46,90] The PAQs must also be validated by an objective measure of PA, which correlates well with gold standard measures.

### 1.3.2 Validation of New Zealand Physical Activity Questionnaires

Validation of the NZPAQs was conducted on a sample of 186 adults (males and females), at least 18 years of age, and included individuals of European/Other, Māori, and Pacific ethnicity. A 3-day HRM period objectively measured PA levels, which were compared to self-reported levels from both PAQs. Specific aims of the validation portion of this study included:

1. Validate the NZPAQ-SF and NZPAQ-LF against HRM in a multiethnic, New Zealand sample of adults aged 18+ years.
2. Compare the NZPAQ-SF with the NZPAQ-LF to assess the robustness of the former.
3. Compare the NZPAQ-SF and NZPAQ-LF against the instrument used in the NZSPAS to assess comparability with previous surveys.
4. Compare the NZPAQ-SF and NZPAQ-LF against an internationally-accepted PAQ to assess comparability with international surveys.
5. Aims 1 to 3 will be repeated in subgroup analyses to determine whether the NZPAQ-SF and NZPAQ-LF are equally valid in ethnic-, gender- and age-subgroups.
6. Develop a short list of physical activities relevant to the adult population in NZ. Should the NZPAQ-SF and NZPAQ-LF fail to be valid instruments this population, this list will contribute culturally-specific activities that could be included in subsequent PA assessments in NZ.
7. Determine the proportions of the sample that engage in resistance training or report split-intensity activities.
8. Compare MET values for occupational PA captured during HRM against estimated MET values reported in the Compendium of Physical Activities.[24]
9. Analysis of the use and impact of translation on self reported PA for the NZPAQ-SF and NZPAQ-LF, by age, ethnicity and gender.

### 1.3.3 Creation of a New Zealand Compendium of Physical Activities

The Compendium of Physical Activities,[24] created in the United States (US), is used internationally to assign MET levels and calculate EE equivalents for an extensive range of PAs. However, this instrument was compiled from a Western population and culturally-specific activities performed in NZ were not included. The objective method of HRM involves an individual calibration procedure that determines HR vs. oxygen consumption ($VO_2$) relationships for each participant, resulting in increased accuracy of individual EE estimates.[35,61] Energy cost calculations were performed for all activities captured and reported during HRM, creating a NZ-specific Compendium of PA intensities.

Creation of a NZ compendium is advantageous for several reasons. Firstly, the commencement of such an instrument offers PA researchers a list of baseline MET levels which more closely reflect activities performed by the NZ population. Future research conducted in NZ can contribute to both the numbers from which MET levels were generated from, and add culturally-specific PAs which were not captured in this study. Secondly, the intensity at which an activity is performed is relative to an individual's age, gender and fitness level. Several activities captured during HRM were further analysed by subgroups. The segregation of MET levels is advantageous for PA research, such as intervention studies, with sample sizes limited to one gender or a specific age group. Finally, associated MET levels for PAs captured in this study could contribute to and be included in an updated version of the US Compendium, if its creators so desire.

### 1.3.4 Cardioprotective Roles of Cardiorespiratory Fitness and Physical Activity

The cardioprotective roles of PA and CRF, expressed as predicted $VO_{2max}$, were examined and compared by performing multiple regression analyses with CV risk factors as the dependent variables. Table 1 lists risk factors and corresponding thresholds for heart disease,[25,91] specific to the NZ population,[92] which were measured in this study.

In addition to BMI, systolic and diastolic blood pressure (SBP and DBP, respectively), associations between fasting blood lipids were also investigated. However, blood test results are available for approximately half the sample (n=92), as this was an optional component offered to participants. Consequently, differences between the samples with and without blood test results were examined for significance. Family history of myocardial infarction, coronary revascularisation, or sudden death was not collected.

Specific aims of this portion of the study include:

1. Examine the relationship between CRF and CV risk factors (BMI, SBP, DBP, TG, HDL-cholesterol, LDL-cholesterol, TC, TC/HDL-cholesterol ratio, fasting glucose).
2. Examine the relationship between PA and CV risk factors (BMI, SBP, DBP, TG, HDL-cholesterol, LDL-cholesterol, TC, TC/HDL-cholesterol ratio, fasting glucose).
3. Determine any differences in the relationships between CRF and PA to CV risk factors.

**Table 1.** Cardiovascular Risk Factors and Thresholds Measured in Study Participants

| Risk Factor | Variables | Defining Criteria |
|---|---|---|
| Cigarette Smoking | N/A | Current cigarette smoker or those who quit within the previous 6 months |
| Hypertension* | Systolic blood pressure<br>Diastolic blood pressure | SBP ≥140 mmHg<br>DBP ≥90 mmHg |
| Hypercholesterolemia | Cholesterol:<br>Total serum (TC)<br>High-density lipoprotein (HDL)<br>Low-density lipoprotein (LDL)<br>Triglycerides (TG) | TC > 5.2 mmol/L<br>HDL-cholesterol < 0.9 mmol/L<br>LDL-cholesterol > 3.4 mmol/L<br>TG > 1.7 mmol/L |
| Impaired fasting glucose | N/A | Fasting glucose > 6.1 |
| Obesity | Body Mass Index (BMI) | BMI ≥ 30.0 $kg/m^2$ for European/Others<br>BMI ≥ 32.0 $kg/m^2$ for Polynesians |
| Sedentary Lifestyle | Physical Activity (PA) | PA ≥ 30 min/day on most, preferably all, days of the week[3] |

*confirmed by measurements on at least 2 separate occasions, or on antihypertensive medication

## 1.4 CHAPTER OUTLINE OF THESIS AND AUTHOR'S ROLE

Chapter 2 is a comprehensive review of literature pertaining to PA and CRF as independent risk factors for CVD. The interrelationship between these two variables, associated health benefits and assessment techniques of each, are discussed. The design and methodology of the study, including data conversions and statistical analyses, are detailed in Chapter 3. Study results are reported in Chapter 4, and Chapter 5 summarises and discusses implications of the findings. Conclusions of this study are brought together in Chapter 6.

Author's Involvement

The author of this thesis was involved with the following aspects of this study:

- Writing of research proposal and ethics application
- Involvement and input into the study design and methodology
- Interviewing, training, and managing research staff
- Liaisons with Māori and Pacific communities for participant recruitment
- Hiring and operating of equipment used during data collection
- Data collection: involvement in all 3 visits, which included conducting interviews, administering exercise tests and physical activity questionnaires, downloading heart rate monitoring data
- Feedback to participants: reporting risk factor profiles and exercise prescriptions (optional) to participants
- Data analyses: coding, creating of datasets, running analyses in SAS
- Data reporting: primary author of "Validation of MOH-short and SPARC-long Physical Activity Questionnaires: Final Report to SPARC. (November 2003)
- Writing all chapters of this thesis

# CHAPTER 2

# REVIEW OF LITERATURE

## 2.1 INTRODUCTION

Literature pertaining to physical activity (PA) was reviewed in detail. Specific topics of interest included PA terms and definitions, associated health benefits, subjective and objective assessment techniques, as well as the distinction between, and relationship with cardiorespiratory fitness (CRF).

<u>Literature Search Strategy</u>

Several computerised searches were performed on Entrez PubMed between June 2002 and December 2004. Identified references were utilised to locate additional literature overlooked by initial attempts. The searches covered literature published between 1985 and 2004, and were performed using the following phrases and combinations:

- Definitions related to physical activity
- Health benefits of physical activity
- Assessing physical activity in adults
- Challenges in measuring physical activity
- Accelerometers AND physical activity assessment
- Heart rate monitoring AND physical activity assessment
- Calorimetry AND physical activity assessment
- Doubly labeled water AND physical activity assessment
- Motion sensors to assess physical activity
- Heart rate monitoring and motion sensors
- Simultaneous heart rate and motion
- Validation of physical activity questionnaires
- Validity of physical activity assessment
- Daily variation AND physical activity
- Cardiorespiratory fitness AND cardiovascular health

National and international websites were also searched for publications related to physical activity, surveillance methods, and associated health benefits. Searched websites included:

- The World Health Organization: http://www.who.int
- United States Department of Health and Human Services, Centers for Disease Control and Prevention: http://www.cdc.gov
- New Zealand Ministry of Health: http://www.moh.govt.nz
- Sport and Recreation New Zealand: http://www.sparc.org.nz

The following inclusion and exclusion criteria were applied to all identified literature:

- Only papers written in the English language were included
- Only studies of adult humans were included

## 2.2 PHYSICAL ACTIVITY

In 1985, Caspersen et al. broadly defined PA as 'the voluntary movement produced by skeletal muscles that result in energy expenditure' (EE).[21] The World Health Organization (WHO) defines PA as 'the entire spectrum of bodily movements that each person can undertake in daily life, ranging from normal active living conditions to intentional moderate physical activities, structured and repetitive physical exercises, physical fitness and training sessions, and collective sport activities, especially leisure and recreational sports'.[37] Today, researchers utilise both definitions, as they highlight the concept of PA as a behaviour that results in EE,[23] and distinguish between PA dimensions and their contributions towards an individual's total energy expenditure (TEE).

### 2.2.1 Physical Activity Dimensions

The mode, frequency, duration, intensity, and context of PAs are typically used to describe individual and population PA levels and patterns,[4-6,28,93] which are important for content validity.[42]

Mode of Physical Activity

Mode of activity refers to the specific activity itself (i.e., walking, cycling, tennis, etc.), but can also be classified into broader types of activity categories (i.e. aerobic, anaerobic, weight bearing or non-weight bearing, resistance or strength activities).[4,5] Aerobic activity involves continuous, rhythmic movement of large muscle groups in dynamic activities.[93] Resistance or strength training activity is performed for the specific purpose of increasing muscular strength, power, and endurance by varying the resistance, the number of times the resistance is moved in a single group (set) of exercise, the number of sets done, and the rest interval provided between sets.[93] Factors such as health, income, social and environmental surroundings will influence the type of activity chosen by an individual.[4]

Frequency of Physical Activity

Frequency refers to how often PA is performed and is measured as the number of days or sessions activity is performed within a particular time period (per day, week, or month).[5,93] The 'last 7 days' is the preferred time period for PA research, as recall of the preceding week is more accurate compared to a generalised recall of 'past week', 'usual week', 'last 2 weeks', 'last month', or 'past year'.[5,94]

Duration of Physical Activity

Duration describes the amount of PA performed within a set time period ('activity session', 'per day', 'last 7 days', 'usual week' or 'last year'), and is typically expressed in hours or minutes.[5] Factors such as age and intensity will influence the duration an activity is performed.[4]

Intensity of Physical Activity

Intensity represents the physical effort required to perform the activity, and is categorised as light, moderate, or vigorous, and is expressed in absolute (objective) or relative (subjective) terms.[5,93] Absolute intensity represents the rate of EE during the activity session and is typically expressed as oxygen uptake in $L \cdot min^{-1}$ or $ml \cdot kg^{-1} \cdot min^{-1}$, EE as kilocalories or kilojoules per min ($kcals \cdot min^{-1}$ or $kJ \cdot min^{-1}$), or metabolic equivalents (METs),[93] which is a universally accepted unit for expressing EE relative to body weight.[22] One MET represents the rate of oxygen consumption ($VO_2$) of a seated individual at rest, equivalent to approximately 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Thus, an individual performing an activity of 4 METs is consuming oxygen at a rate 4 times that at rest.[25]

When the absolute intensity of an activity cannot be directly measured, the associated METs can be retrieved from the Compendium of Physical Activities, which was developed to facilitate coding and comparison of PA types and intensities by providing respective MET values for an expansive range of activities.[24,95] Absolute cut points for PA intensities, in accordance with guidelines set forth by the Center for Disease Control (CDC) and the American College of Sports Medicine (ACSM) are presented in Table 2, although these cut points vary slightly between studies.[2] Descriptions of the physical effort associated with respective intensities, which are typically provided to assist participants when reporting activities of specific intensities on physical activity questionnaires (PAQs),[28] are also presented.

**Table 2.** Intensity and Definitions of Absolute MET Values

| Activity Intensity | MET value | Description of Intensity Level |
|---|---|---|
| Light | < 3 METs | Does **not** cause you to breathe harder than normal |
| Moderate | 3 - 6 METs | Makes you breathe harder than normal, **but only a little** |
| Vigorous | > 6 METs | Makes you breathe **a lot** harder than normal ('huff and puff') |

Absolute cut points are acceptable for classifying intensity of activities performed by individuals or populations of similar age, ability and fitness levels, but most physiological responses to exercise are dictated by the relative intensity,[26] which is influenced by factors such as age, gender, weight, disability, and fitness level.[3,5] Age-specific absolute intensity classifications[25] are presented in Table 3. For example, a young, active and fit individual could perform an activity at a given workload with little effort, while an older, sedentary and less fit person may find the same activity requires maximal physical effort, representing a higher relative intensity.[26,27,96] To account for this variation, the relative intensity of aerobic activity can be calculated from maximal physiological responses, and expressed as percentages of the following: maximal oxygen uptake ($VO_{2max}$), oxygen uptake reserve, heart rate reserve (HRR), or maximal heart rate ($HR_{max}$).[29,93]

Subjective measures can also be recorded using Borg's Ratings of Perceived Exertion (RPE) Scale. The individual is asked to subjectively rate their exertion level, based on physical sensations during PA, including increased heart rate (HR), increased respiration or breathing rate, increased sweating, and muscle fatigue. The original RPE scale rated activity intensity on a scale of 6-20, and has been revised to a 0-10 scale (Table 3), which is better understood by participants. Although this is a subjective measure, RPE values correlate highly with exercise HR and provide an indication of the relative exercise intensity.[25]

**Table 3.** Classification of Absolute Physical Activity Intensity by Age Group

| Absolute Activity Intensity (METs) in Healthy Adults | | | | | |
|---|---|---|---|---|---|
| **Intensity** | **Young (20-39 yrs)** | **Middle-aged (40-64 yrs)** | **Old (65-79 yrs)** | **Very Old (80+ yrs)** | **RPE*** |
| Very Light | <3.0 | <2.5 | <2.0 | ≤1.25 | <1 |
| Light | 3.0-4.7 | 2.5-4.4 | 2.0-3.5 | 1.26-2.2 | 1-1.5 |
| Moderate | 4.8-7.1 | 4.5-5.9 | 3.6-4.7 | 2.3-2.95 | 2-2.5 |
| Hard | 7.2-10.1 | 6.0-8.4 | 4.8-6.7 | 3.0-4.25 | 3-5 |
| Very Hard | ≥10.2 | ≥8.5 | ≥6.8 | ≥4.25 | 6-8 |
| Maximal | 12.0 | 10.0 | 8.0 | 5.0 | 10 |

*RPE = Ratings of Perceived Exertion

Context of Physical Activity

PA contexts refer to the purpose or circumstances under which activities are performed. Three main PA domains have been identified by the WHO: leisure-time (LTPA) or sport and recreation, occupation, and transportation.[97] Physical activities that don't take place under these contexts, such as household activities, can be classified as Incidental/Other[4,5].

- **Leisure-time (LTPA):** refers to activities performed during an individual's spare time, and includes organised and informal sports, hobbies such as gardening or surfing, exercises performed at the gym or at home, etc. The main distinguishing factor is that activities are voluntarily performed for enjoyment or relaxation, and are based on personal interests. LTPAs vary considerably in regard to intensity and duration, but result in a substantial increase in EE.[93]

- **Occupation:** refers to physical activities associated with job performance and is an important context to acknowledge separately, as the majority of TEE in developing countries and lower economic groups appears to take place while performing job-related tasks.[5,7,8] This context has a typical timeframe of an 8-hour work day.[93]

- **Transport/Travel:** describes activities undertaken for the purpose of getting from one place to another, usually across a reasonable distance,[71] and may be a significant contributor to PA levels/total EE in some populations. Walking and cycling are the most common activities reported.[7,8]

- **Incidental/Household/Other:** activities typically performed in the household such as domestic chores, family/child care, yard work, etc. This domain appears to be more relevant to women,[7] particularly minority women[49] and lower economic status.[5,47] Incidental PAs can substantially contribute to an individual's daily TEE.[7,8] The intensity at which incidental activities are performed vary widely. Furthermore, activities such as gardening or yard work may show a strong seasonal effect.[8]

### 2.2.2 Definitions of Related Terms

The term 'physical activity' is often used interchangeably with 'physical fitness', 'exercise', or 'energy expenditure'[21,36,42] and misinterpreted by different population groups.[8,49] Standardising the definitions and applications of terms related to PA is imperative for facilitating direct comparisons and interpretations between research findings from different populations.[8,23,40]

- **Physical fitness:** a set of attributes that people have or achieve, which relate to the ability to perform physical activities[21] that require endurance, strength, or flexibility.[71] Physical fitness is determined by a combination of PA patterns over recent weeks or months, and genetically inherited ability.[71,72] The two components of physical fitness are health-related fitness and skill-related fitness.[21]
    - Health-related fitness: cardiorespiratory fitness/endurance, muscular endurance, muscular strength, body composition, and flexibility
    - Skill-related fitness: agility, balance, coordination, speed, power, and reaction time

- **Cardiorespiratory fitness:** a health related component of physical fitness representing the ability of the circulatory and respiratory systems to supply $O_2$ during sustained PA[3,71]

- **Exercise:** The formula relating PA and exercise is [21]:

  $$\text{kcal}_{\text{exercise}} + \text{kcal}_{\text{non-exercise}} = \text{kcal}_{\text{total daily physical activity}}$$

  Tasks performed in labour-producing rather than labour-saving manners are classified as exercise.[21] The distinguishing element is that exercise is planned, structured, and repetitive bodily movements performed for the specific purpose of improving or maintaining one or more components of physical fitness,[21,71] performance, or health. Exercise can also provide a means of social interaction.[4]

- **Energy Expenditure:** The product of intensity, frequency and duration of activity determines net caloric expenditure from the activity.[25] EE is inversely related to cardiovascular (CV) morbidity and mortality, and all-cause mortality.[3-12,96] EE is heavily influenced by body weight[21,22] and other factors such as age, gender and fitness level.[23,43] Similar TEE values are found between active, light-weight individuals and sedentary, heavy individuals.[22] Expressed as a rate in kcals/min, individual EE is a continuous variable, ranging from low to high.
  - <u>Activity Energy Expenditure (AEE)</u>: The energy cost associated with a given activity, typically expressed in units of kilocalories (kcals) or METs, which corrects for body weight.[22,23] The rate of EE can differ considerably between two activities despite having similar AEE values (i.e. short duration, high-intensity activities can yield similar AEE values as long duration, low-intensity activities).[22]
  - <u>Total Energy Expenditure (TEE)</u>: Refers to total daily EE and consists of three components[22,33]:
    1) Resting metabolic rate (RMR): Accounts for 60-75% of TEE, and is the EE required to maintain body temperature and involuntary muscular contraction for functions such as circulation and respiration.
    2) Thermic effect of food: Refers to EE associated with functions such as digestion and assimilation of food. Accounts for approximately 10% of TEE.
    3) AEE: The most variable TEE component, accounting for 15-30% of TEE.

- **Physically Inactive:** Minimal or no regular pattern of PA beyond daily functioning.[71] Physically inactive behaviours include sleeping, eating, standing still, sitting, television viewing, reading, working on a computer, talking on a phone and passive commuting (e.g. riding on a train or in a car).[43]

### 2.2.3 Current Physical Activity Recommendations in New Zealand

Current New Zealand (NZ) recommendations for PA[6] were derived from the United States (US) Surgeon General's Report[3] that advocates 30 minutes of at least moderate-intensity endurance-type PA on most, preferably all, days of the week. This recommendation highlights the significance of maintaining a minimum level of cardiorespiratory fitness (CRF), important for reducing the high coronary heart disease (CHD) morbidity and mortality rates in NZ.[4] Experts also recommend supplementing endurance activities with strength-developing exercises at least twice per week.[3]

The threshold level of PA required for health depends upon the desired health outcomes and the current health conditions that an individual has or is at risk of developing.[4] For example, obese individuals would primarily focus on TEE, persons with osteoporosis would concentrate on resistance training, and improving cardiorespiratory fitness would be the main focal point of individuals with CHD.

Physical Activity Dimensions: Recommendations and Health Benefits

Different PA dimensions are associated with different health benefits. Specific recommendations exist for each PA dimension, depending on individual capability and health outcomes goals.

- **Mode:** Participation in endurance activity produces the greatest improvements in CV health.[25]
    - Additionally, resistance or weight-bearing activities benefit bone and joint health which is important for individuals at risk of osteoporosis and osteoarthritis.[3,4,71]

- **Frequency:** PA provides maximum health benefits when spread over 5 days per week.[4]
    - When PA is performed throughout the week, an individual's metabolic rate is increased for a longer time period, compared to performing a large amount of PA on one day. This has health benefits associated with weight loss/maintenance, cardiac function, and diabetes prevention.
    - Continuous, long-term benefit occurs when PA is integrated into an individual's lifestyle.
    - Many of the health benefits of PA appear to decline on cessation of activity, although some benefits persist on cessation, suggesting that activity performed when young may influence health in older age.

- **Duration:** 150 minutes of moderate-intensity activity per week is the recommended threshold.
    - Research has found similar CV benefits between one 30-minute session of PA and several shorter sessions (e.g. three 10-minute sessions) of moderate-intensity activity per day.[2,3,98] This concept, also known as 'snacktivity', provides incentive to individuals with time constraints by reinforcing that shorter episodes of PA result in greater health gains than none at all.[3,4] Additionally, 'snacktivity' introduces PA in a less intimidating manner and provides beginners with realistic, attainable goals.[2]
    - It has been suggested that the current recommendation of 150 minutes per week may be an overestimation of the threshold required for benefit. A recent study has found that women who spend an hour per week walking at a moderate intensity can cut their risk of heart disease in half .[99]

- **Intensity:** Activity intensity has a direct impact on the magnitude of CRF improvements and is related to various health outcomes.[26,42] Regular participation in PAs of at least moderate-intensity is recommended.
    - Light-intensity activity is the introductory level recommended for individuals unaccustomed to regular PA. However, capable individuals should gradually advance to moderate- and vigorous-intensities for increased benefit.[4]
    - Activity intensity has a dose-response relationship to health benefits, particularly for cardiovascular disease (CVD).[6] However, performing PA at any intensity will result in health benefits.

- **Energy Expenditure:** The current recommendation corresponds to an EE level of at least 1,000 kcals per week, and is the minimum recommendation for substantial health benefits, regardless of exercise duration or intensity.[25]
    - Health benefits are maximised at 2,000 kcals per week, beyond which no further benefit accrues.[10]
    - For persons with weight loss goals, 300 kcals per exercise session is recommended.[25]
    - EE has an inverse relationship to all-cause mortality, CV morbidity and mortality, Type 2 diabetes, hypertension, site-specific cancers, and obesity.[4,96] The recommended level of EE can be achieved by either performing lower-intensity PAs for longer durations, or higher-intensity PAs for shorter durations.

### 2.2.4 Health Benefits of a Physically Active Lifestyle

This section summarises the benefits of PA, which is recognized internationally as a key factor in the maintenance and improvement of physical, physiological and psychological health.[2,3] Individuals who meet the minimum PA recommendations have a 30% reduced risk of coronary artery disease, stroke, and type 2 diabetes.[14] Additionally, the onset, severity, and frequency of these diseases and their symptoms in active, fit individuals tends to develop later and at a lesser extent, compared to inactive, unfit individuals.[4,40] Other diseases and conditions improved by regular PA include[2-7,12,13,15]:

- CVD and stroke
- Type 2 diabetes
- Cancers (breast, colon, endometrium, lung, prostate)
- Chronic obstructive respiratory disease
- Osteoporosis and osteoarthritis
- Asthma (review of 8 studies, and case control studies in Finland and Denmark)[37]
- Smoking
- Obesity
- Hypertension
- Blood lipids
- Body composition
- Bone density
- Immune function
- Depression, anxiety, stress

### 2.2.5 Global Epidemic of Physical Inactivity

The epidemic of physical inactivity is an issue of global concern.[13-17] Chronic diseases and health conditions causally related to modifiable risk factors are now the leading causes of death in developed and developing countries, with the exception of sub-Saharan Africa, where infectious diseases are the leading problem.[8,13] The inverse dose response relationship of physical inactivity to poor health and mortality is independent of other major risk factors.[4,10,15,18,25,40,82,100] As the prevalence of other risk factors such as tobacco smoking, hypertension, and adverse blood lipid profiles are decreasing, obesity, a result of physical inactivity, continues to rise around the globe.[13,15,17,101] Approximately 60-85% of the world population lead sedentary lifestyles, and an estimated 2 million deaths per year are attributed specifically to physical inactivity.[13] Sedentary Death Syndrome (SeDS) is a new term which emphasizes the relationship between physically inactive lifestyles and premature death.[14]

Population attributable risk (PAR) can be used to explain the health burden imposed by physical inactivity. PAR is defined as the percentage of a given health outcome attributable to inactivity in the population.[102] Although research measures and definitions for sedentary or insufficiently active lifestyles differ, PARs from around the world range from 40% in the Netherlands,[103] to 75% in Finland, Sweden, and the US.[102] Physical inactivity PARs in NZ, reported by Galgali et al.[104], were 30% for diabetes and 35% for CHD. These numbers indicate the percentages of deaths which could theoretically be prevented if the entire population were sufficiently active, and that the public health burden of physical inactivity is at least of the same magnitude of smoking, and about three times greater than obesity or the excess intake of saturated fatty acids.[103] A recent study based in Hong Kong cited that lack of PA caused more annual deaths than tobacco smoking.[18]

The Economic Burden of Physical Inactivity in New Zealand

Physical inactivity, defined as 'less than 2.5 hours of participation in weekly leisure-time PA',[105] is responsible for an estimated 2,600 deaths per year in NZ.[106] The 1998 Sport and Physical Activity Survey (NZSPAS) and the 1996/1997 NZ Health Survey (NZHS) reported 34% and 39% of adults were physically inactive, respectively. Additionally, 10% and 15% of adults were classified as sedentary, defined as no participation in leisure-time PA in the last month.[5,10] Galgali et al.[107] estimated inactivity levels of older adults in Auckland, NZ, by extrapolating study population data to 1991 census population data, and reported nearly 40% of older adults did not participate in leisure-time physical activities. Furthermore, 6.1% of older adults were considered physically inactive, and non-participation was greater in older females (7.7%) compared to older males (4.1%).[107]

Overweight and obesity, adverse health conditions associated with a physically inactive lifestyle, are increasing in NZ and many other Western nations.[6,10,20,101,108] Degrees of overweight and obesity are determined by an individual's body mass index (BMI), which calculates body weight in kilograms (kg) relative to height ($m^2$), and differs between NZ European and Polynesian ethnic groups (Table 4).[109] Prevalence of overweight (35%) and obesity (17%) increased by 55% between 1989-1997[6,10] and were projected to increase 70% by 2011.[26] In 1996, a conservative estimate of annual health care costs for obesity-related diseases and conditions was $135 million.[20] In addition to direct economic costs associated with overweight and obesity, delivery of health care and indirect costs such as early retirement, increased risk of disability pensions, and the cost of human suffering and lives lost prematurely also contribute to the economic burden of physical inactivity.[19,20]

Greater public health gains will be achieved by encouraging large numbers of sedentary individuals to moderately increase PA, as opposed to targeting a smaller group to make large PA changes.[3,15,110] In fact, the CDC reported that the health benefits from increasing PA were 9 times greater in sedentary individuals, compared with those who were already physically active.[2] This notion is supported by the following calculations:

- If 3-8% of the population moderately increased participation in PA, 4% of deaths and $24 million could be saved.[6]
- If 10% of the population moderately increased activity levels, 600 deaths and a minimum savings of $55 million per year could be prevented.[6,11]

**Table 4.** Ethnic-specific Body Mass Index (BMI) Classifications[109]

| BMI Classification | European/Other | Pacific/ Māori |
|---|---|---|
| Underweight | <20.0 | <20.0 |
| Desirable | 20.0-24.9 | 20.0-25.9 |
| Overweight | 25.0–29.9 | 26.0-31.9 |
| Obese | ≥30.0 | ≥32.0 |

## 2.3 CARDIORESPIRATORY FITNESS

### 2.3.1 Cardiorespiratory Fitness: Definition and Components

Physical fitness is defined as a set of attributes that people have or achieve that relates to the ability to perform PA.[21] A number of factors contribute to an individual's general fitness level, which is comprised of skill-related (agility, balance, coordination, speed, power, and reaction time), and health-related components (cardiorespiratory endurance, body composition, muscular strength and endurance, and flexibility).[25,89] The term 'cardiorespiratory fitness', often used interchangeably with cardiorespiratory endurance, aerobic capacity, and aerobic, CV, or physical fitness, refers specifically to the ability of the CV and respiratory systems to supply oxygen ($O_2$) to working muscles during sustained PA.[21,93] An individual's CRF level is primarily determined by aerobic PA patterns over recent weeks and months,[72] while 25-40% of the variation in CRF levels is explained by genetics,[73] and factors such as age, gender, medical status, and selected health-related behaviours also make contributions.[74] The genetic component of fitness is demonstrated by the fact that although higher PA levels are associated with higher fitness levels,[78,82] the magnitude of response to PA stimulus between individuals will vary greatly.[82] Nonetheless, higher CRF levels allow individuals to perform moderate- and vigorous-intensity activities for prolonged periods of time.[25,65] CRF is assessed by both submaximal and maximal responses to exercise testing, which will be addressed in more detail in Section 2.3.3.

### 2.3.2 Cardiorespiratory Fitness and Health

In the 1960's, early investigations into CRF levels reported consistent, inverse associations with risk factors for CVD[83] and CHD.[79] The abundance of research concurs that CRF is significantly associated with lower morbidity and mortality rates for CHD,[23,40,75,79,80,111] CVD,[30,40,76,81-83,88] Type 2 diabetes,[84] stroke,[112] the metabolic syndrome,[85-87] and premature death from all causes in men and women independent of other major risk factors.[40,78,80,82,88,89] Furthermore, these associations are steeper in unfit individuals, who have a 50% and 70% higher mortality rate compared to their moderately-fit and high-fit counterparts, respectively.[82] Lower CVD and all-cause mortality rates were also observed in obese, moderately fit individuals compared to normal weight, unfit individuals.[87]

Health Outcomes: Cardiorespiratory Fitness vs. Physical Activity

The emergence of the protective role of CRF with major chronic diseases and conditions prompted debate and further investigation into the CRF vs. PA relationship in regard to health outcomes.[30,40,82,84,87,113] The notion of accumulating moderate-intensity PA raised questions about the resulting benefits. Although the health benefits associated with moderate-intensity PA are well-known, vigorous-intensity PA improves CRF and longevity.[82,114] Blair et al.[72] conducted a meta-analysis of 56 PA and 11 CRF-related health research studies and found an inverse dose-response for most health outcomes and mortality across PA levels. Although CRF studies are typically limited to small sample sizes of mainly healthy, Caucasian men,[82,111] results showed consistently stronger and steeper dose response curves compared to PA studies.[82] That said, CRF assessments are more objective, precise and reliable, with less measurement error and opportunity for misclassification compared to self-report PA assessments, and could explain the stronger associations between CRF and health outcomes.[82,111] Greater health outcomes associated with CRF compared to PA are also evident in older adults.[76,77] Dvorak et al.[76] reported significantly greater cardioprotective effects associated with CRF levels in older adults, regardless of PA level. This was evident in blood profiles ($P<0.05$), including fasting insulin, triglycerides (TG), total cholesterol (TC), ratio of TC to high density lipoprotein cholesterol (TC/HDL-cholesterol), low density lipoprotein cholesterol (LDL-cholesterol), and waist circumference ($P<0.01$).[76]

Physical inactivity and CRF are recognised as separate risk factors, both worthy of measurement to provide more complete risk profiles.[112] Public health recommendations in the US currently advocate increases in PA and CRF levels for primary and secondary CHD prevention.[78] Increased PA must be encouraged, as this behaviour is required for the development and maintenance of CRF levels consistent with good health.[82]

### 2.3.3 Cardiorespiratory Fitness Assessment

Individual CRF levels depend on proper functioning of the respiratory, CV, and musculoskeletal systems, and are typically assessed in a laboratory via indirect calorimetry during a graded exercise test.[89] The criterion measure of CRF is $VO_{2max}$, which is a direct, objective measure of an individual's highest rate of oxygen ($O_2$) uptake achieved during large muscle, dynamic PA requiring maximum effort.[25,65,89] $VO_{2max}$ is used to classify individuals according to age- and gender-matched norms,[25] and can be expressed either in absolute terms as litres of $O_2$ consumed per minute ($L \cdot min^{-1}$), or in relative terms as millilitres of $O_2$ consumed per kg of body weight per minute ($ml \cdot kg \cdot min^{-1}$).[25,89] Factoring in body weight allows for comparisons between people of varying size in different environments, although this has the potential for unfairly underestimating CRF levels in individuals with high body fat.[89]

Submaximal vs. Maximal Exercise Testing

Conducting CRF tests requires expensive metabolic equipment and qualified test administrators to calibrate and operate the equipment, interact with and closely monitor the participants, interpret the data, and operate emergency equipment if necessary.[25,40] CRF can be assessed with either maximal or submaximal exercise testing, each with advantages and disadvantages. Prior to determining the most appropriate technique, several issues must be considered by the investigator[25]:

1. Purpose for exercise testing
2. Sample size to be tested
3. Overall health status and fitness level of subjects (is physician supervision required?)
4. Cost requirements for equipment and test administrators
5. Time requirements for participants and researchers.

Although $VO_{2max}$ is the criterion measure of CRF, maximal exercise testing imposes a high participant burden in terms of time, effort, cooperation and risk, as well as the time and effort required by the testing staff, therefore limiting its feasibility in epidemiological studies.[25,40] There is a heavy reliance on participant cooperation and willingness to perform at exhaustive workloads, which limits the appropriateness of this technique to motivated, healthy individuals as the risk to elderly or those with pre-existing heart conditions requires physician supervision.[25]

Submaximal exercise testing offers an alternative to maximal exercise tests which decreases participant burden and risk.[25,40] However, several assumptions are associated with submaximal exercise tests which introduce unknown errors when predicting $VO_{2max}$.[25,89] Additionally, variables such as the testing environment and the participant's behaviour and diet can affect submaximal HR responses. In an effort to control for and minimise these effects, pre-exercise test instructions are provided and must be adhered to by the participants.[25]

The standardised exercise protocol estimates $VO_{2max}$ by extrapolating submaximal HR responses to an age-predicted end point,[25,93] which represents the highest HR attainable during maximal effort PA, to the point of volitional fatigue.[3] Submaximal exercise testing is associated with two underlying assumptions:

1. A linear relationship exists between individual HR and $VO_2$
2. Individual age-predicted $HR_{max}$ (220 – age in yrs) is a reasonably accurate estimate

These underlying assumptions are met when submaximal exercise tests are administered on large samples of healthy adults.

<u>Exercise Test Modalities</u>

Cycle ergometers and treadmills are the preferred exercise test modes because the low skill level associated with walking or cycling limits the amount of interindividual variation in mechanical and metabolic efficiency,[40] although step tests and field tests are also performed.[25,89] While treadmills and cycle ergometers are favoured exercise testing modalities, each has advantages and disadvantages which require consideration.

Compared to treadmills, cycle ergometers are easily transportable, relatively inexpensive equipment which allow for non-weight bearing activity to be performed in different locations. The stationary nature of cycle ergometers facilitates blood pressure (BP) measurements during exercise testing (if necessary), and the low risk of falling reduces anxiety levels often associated with treadmills.[25,41,89] Maintenance of a constant pedalling rate is required so that recordings can be measured at specific work rates,[25,46] although this can easily be achieved by providing assistance from a metronome and close monitoring by researchers. The main drawback associated with cycle ergometers is that individuals unaccustomed to cycling are prone to lower limb muscular fatigue prior to reaching maximum cardiorespiratory ability,[25] resulting in early test termination and erroneously low $VO_{2max}$ values.[65,89]

## 2.4 SUBJECTIVE MEASURES OF PHYSICAL ACTIVITY

Instruments that rely on self-report measures are the most common approach to quantifying PA levels and patterns in free-living adult populations.[42] The feasibility of self-report instruments applies to developed and developing countries.[8] The three main types of instruments are recall instruments, physical activity logs (PA Logs), and PA diaries. They are subjective instruments that can be self- or interview-administered,[42] and differ in regard to the reference periods, type of activity assessed, and the targeted population.[41,46] Individual data obtained from self-report measures are typically converted into estimates which allow researchers to categorise or rank individuals or populations by PA level.[3,47] There is no single instrument that adequately measures habitual PA and all of its components and dimensions.[34,60] Instead, the instrument of choice should be appropriate for the targeted population and will be influenced by research aims and budget. Each instrument discussed below has advantages and disadvantages.

### 2.4.1 Physical Activity Questionnaires

The most practical self-report instrument for population PA research is the PAQ, which is advantageous to other self-report measures for several reasons[3,22,25,41,42]:

- Wide distribution allows researchers to collect data from a large number of people
- Low cost
- Applicable to a wide range of ages
- Recalls do not alter current behaviour under study, which can occur with PA logs and diaries
- Measures can be adapted to fit the needs of a particular population or research question
- Ability to assess all PA dimensions and PA patterns
- Can be administered in several ways (mailed forms, face-to-face, telephone interviews)

PAQs vary in detail, reference period, administration, completion time and how respondents are classified. Lengthy PAQs can cause boredom or confusion which will affect the validity and reliability of the instrument.[29] Due to their subjective nature, PAQs are inherently limited by several factors such as recall error, bias, floor effects, misinterpretation of terminology, and failure to quantify the totality of PA in all dimensions and contexts.[8,28,31,38,40,42,46,48,49]

Self-reporting of the duration, frequency and intensity of activities is subject to recall error.[48] Vigorous-intensity activity is more accurately recalled compared to low- and moderate-intensity activities,[33,38,39,43,46,47] which are difficult for respondents to distinguish between.[28] Consequently, activity intensities are typically overestimated,[28] particularly in sedentary[115] and unfit adults.[22] Similarly, structured activities such as organised sport are more easily recalled because the activities are intentional and have discrete time periods.[46] As a result, recall error associated with PA dimensions limits the accuracy of quantifying activity levels and patterns in their entirety.[46]

PAQs can be influenced by social desirability and gender biases.[29,31,42] Participants are inclined to report a socially-acceptable level of activity, and typically over- and under-estimate time spent physically active and sedentary, respectively.[42] The majority of earlier PAQs focused primarily on vigorous-intensity sports and exercise and physically active hobbies, which women seldom perform.[30,31] Instead, the majority of women's activities occur in the household, on the job, or travelling from place to place. Failure to capture activity levels in all contexts can lead to underestimations of PA levels, particularly in women.[30,31]

Terminology such as 'leisure-time', 'moderate-intensity', 'physical activity' or 'exercise' is characteristic of PAQs. However, the ambiguity of these terms exposes them to misinterpretation within and between different cultures and populations, and translations are often required.[8,49] Furthermore, respondents' interpretations of such terms may be quite different to those of the researchers.[42] For example, some individuals may associate the term "exercise" with vigorous-intensity, structured activities or sports, and exclude enjoyable activities such as dancing.[8]

Until recently, PAQs were designed to quantify only LTPAs, and information relating to PA intensity was sometimes overlooked.[6,28,29] It is important to measure PA levels on the lower end of the intensity spectrum, as special populations such as extremely sedentary or frail elderly individuals will benefit from small amounts of activity. Consequently, instruments incapable of capturing incidental, lower-intensity activities suffer from 'floor' effects (i.e. the lowest score available is too high for some respondents)[43] and misclassifications.[28] Two New Zealand physical activity questionnaires (NZPAQs) have since been developed to measure the duration, frequency, and intensity of PAs performed in all contexts (sports and recreation, occupation, transportation, and incidental lifestyle activities).[28]

Global Physical Activity Questionnaires

Global PAQs aim to quantify population PA measures, for the purpose of surveillance, using a limited number of questions, typically one to four items.[23,47] The desired outcome is to obtain meaningful PA data in the widest possible set of national and cultural contexts. These instruments are designed for easy administration with minimal burden to the respondent in regard to completion time and memory recall.[47] However, global surveys are limited to simple classifications, as information on specific types and patterns of PA are not typically captured.[23]

### 2.4.2 Physical Activity Logs

PA Logs are continuous records of participation in specific types of listed activities.[3] The respondent is required to record the duration and intensity immediately or shortly after one of the listed activities is performed.[40] This information can be utilised to calculate the energy cost of each activity and determine the accumulated EE of daily activities.[8,95] However, the respondent burden is much greater compared to PAQs,[3,40] and estimates of activity intensity are based on the individual's interpretation, which reflects relative intensity rather than absolute intensity.[40]

### 2.4.3 Physical Activity Diaries

The diary technique of assessing habitual PA consists of periodic recording of all activities, either by the individual, an observer, or an interviewer.[41] Activity diaries are superior to activity recall[32] and are capable of simultaneously collecting data on many subjects at low cost. Recording frequency is determined by the investigator, and has ranged from every minute to every 4 hours, typically limited to 1-3 days.[3] The detail of diary entries also varies, and can be meticulous records on every single activity throughout the day,[40] or logging of specific activities to be assigned to general categories.[22]

However, PA diaries are far more tedious and demanding than recall questionnaires and PA logs,[40] for respondents and researchers.[22,40] Researchers can decrease respondent burden of diary entries by providing symbols to be used as shorthand or only requesting recordings of changes in activities. However, normal daily routines are frequently interrupted to make diary entries, which require total dedication and cooperation from the participant.[22] That said, this technique may not be feasible for some populations. For the researcher, diary entries can be very expensive and time consuming to process. Reference periods should be limited to short time periods for obtaining accurate data.

## 2.5 OBJECTIVE MEASURES OF PHYSICAL ACTIVITY

Accurate assessment of the dimensions and contexts of PA requires an instrument which objectively quantifies free-living PA.[38] There are several existing instruments ranging in price, complexity, mechanism and feasibility for epidemiological studies.

### 2.5.1 Motion Sensors: Pedometers and Accelerometers

Pedometers and accelerometers are small motion sensors worn at the trunk or a limb designed to record acceleration counts and estimate the energy cost of activities or TEE.

Pedometers

Pedometers are small, belt-mounted devices primarily used for quantifying the daily number of counts (i.e. steps) accumulated.[33,38,116] Each step is recorded as the hip's vertical accelerations trigger a spring-suspended horizontal lever arm.[116,117] Total daily steps can be compared to the proposed activity classifications in Table 5:

**Table 5.** Physical Activity Classifications based on Daily Pedometer Counts[43]

| Number of Daily Counts Accumulated | Activity Classification |
|---|---|
| < 5,000 | Sedentary |
| 5,000 – 7,499 | Inactive |
| 7,500 – 9,999 | Somewhat Active |
| ≥ 10,000 | Active |

Pedometers provide accurate data and are capable of detecting dose-response relationships between total daily steps and cardiovascular (CV) risk factors, as well as the age-related decline in walking.[116] These instruments also serve as motivational tools for promoting PA[38,117] because immediate feedback on accumulated steps, whether incidental or intentional, provides goal attainment information as well as a constant reminder to be active.[38,117] These characteristics, as well as size, cost, and self-monitoring capability allow pedometers to play a key role in health promotion campaigns and walking intervention studies.[38]

Several models of pedometers exist, and some are capable of estimating total distance walked or total caloric expenditure if the individual's stride length or body weight is measured and entered into the device.[38] However, these estimations are associated with more measurement error compared to daily steps accumulated[32,117] because pedometers are incapable of distinguishing between walking and running activities,[116] individual variation in stride rate and speed,[118] and the foot-to-surface impact.[119] Measurement error is also increased during locomotive and lower body activities.[38,116]

Furthermore, pedometers have several limitations as research tools if the purpose is to evaluate PA patterns, as these instruments lack the internal clocks, data storage abilities, and sensitivity required to quantify the frequency, duration and intensity of activities.[38,116,119] Although they produce accurate step counts, pedometers do not provide information during non-ambulatory activities (i.e. cycling, weight training, and swimming) and isometric exercises or activities that involve the upper body.[38,116,117,119]

Uniaxial Accelerometers

Uniaxial accelerometers are also small, unobtrusive instruments but are more complex than pedometers. These instruments can be worn at the trunk and/or limbs to monitor the intensity of acceleration and deceleration of the body mass, usually in the vertical plane.[32] Accelerometers calculate TEE or AEE based on the theory that acceleration is directly proportional to the muscular forces required for movement, and therefore is related to EE.[38] An individual's age, sex, height and weight can be inputted to estimate RMR, which is summed, along with the vertical accelerations detected by a piezometer, to produce a cumulative score used to estimate TEE.[38,120] Accelerometers are appropriate for a wide variety of activities,[32] and their memory capacities range from days to several weeks, depending on the model.[32,121] Another advantage over pedometers is that accelerometers provide temporal information (frequency and duration) on PA patterns, and some models can download data to a personal computer.[121]

However, several studies criticise accelerometers for lacking the sensitivity required to accurately quantify exercise intensity and AEE over a wide range of lifestyle activities.[32,48,51,52] Erroneous accelerometer estimates have been associated with many low- and high-intensity activities such as standing, childcare, house and yard work, occupational activities, swimming, weight lifting, upper body activities, static work, or activities where the body weight is partially supported, as in bicycling or rowing.[48,51-54] Furthermore, increases in metabolic costs associated with pushing or carrying loads, performing activities on soft surfaces, or walking/jogging with changes in grade or velocity are also undetectable with accelerometers,[38,48,51,52,55] although one study reported accelerometers to be very sensitive to changes in terrain or other uncontrolled conditions such as fatigue while walking or jogging.[118] That said, accuracy varies with different brands of accelerometers. The Caltrac has reportedly overestimated EE during brisk walking and slow jogging by 20-40%,[51] while the Computer Science and Applications, Inc. (CSA) has produced valid EE estimates during level walking and running between 3-6mph.[33] The addition of a limb-mounted accelerometer was a strategy proposed to increase the accuracy of EE estimates in activities involving site-specific movements, although it was concluded that capturing the additional information in this manner would not be justified by its cost.[48]

Triaxial Accelerometers

Triaxial accelerometers are 3-dimensional instruments that capture more detailed information on the temporal patterns of free-living activity compared to uniaxial accelerometers.[32,38] These instruments measure the intensity, frequency, duration and total volume of activity in up to three planes: anterior-posterior, lateral, and vertical.[35,59] Similar to uniaxial accelerometers, movement over user-specified time intervals is stored as acceleration counts (the Tritrac model can store up to 14 days of data),[57] but triaxial models store accumulated counts for each individual plane and all planes combined to estimate TEE and AEE.[35,38] This method of assessing energy costs is a convenient and non-invasive procedure[35] which involves minimal burden to the participant.[59] The advantages to the researchers include a reduced risk of subject tampering, and a simplified process to retrieve and download data to a computer.[57]

Although triaxial accelerometers provide more significant information on 3-dimensional activity, the precision of EE estimates remains hindered by the inability to measure static work and to distinguish between small and large limb movements against a grade.[32,35] Triaxial accelerometers exhibit similar limitations to uniaxial models in that activity EE is underestimated for weight lifting, stationary bicycling, upper body activity, carrying loads, and walking uphill.[57]

Similar to the uniaxial versions, triaxial accelerometers consistently underestimate TEE in free-living conditions by significantly overestimating EE during sedentary activities and underestimating AEE of low-, moderate-, and vigorous-intensity activities.[38,56,57,122] In 1995, Welk and Corbin[122] found very comparable correlations between uniaxial (Caltrac) and triaxial (Tritrac) accelerometer estimates from a field setting. This finding supports Montoye's[22] statement that additional information captured by a triaxial accelerometer would not be justified by the cost. In contrast, Freedson et al.[38] found triaxial accelerometers elicited higher correlation coefficients and improved EE estimates compared to uniaxial models.

<u>Summary of Motion Sensors</u>

Regardless of cost or complexity, motion sensor data are best analysed as counts, since pedometers and accelerometers generally underestimate free-living EE.[56,57] While motion sensors accurately detect changes in speed, they remain limited by their inability to track changes in slope. Consequently, motion sensors alone are unable to adequately assess daily EE when significant amounts of activity involve climbing stairs or hills, or when increases in activity intensity are due to resistance rather than speed or frequency of movement.[51]

Furthermore, these instruments are not ideal for large-scale studies for several reasons:

- Motion sensors are not usually waterproof so cannot be worn while swimming, which is a common leisure activity.[52]
- Motion sensors are prone to instrument malfunction.[38]
- Accelerometer output is affected by anthropometric measures (i.e. leg length and height),[59] and published cut-off values need to be population-specific
- Instrument validation should be based on a variety of free-living physical activities,[59] which motion sensors are unable to detect accurately.[32,35,38,48,51-55,58]

### 2.5.2 Heart Rate Monitoring

An individual's HR is the easiest physiological variable to measure in the field.[22] Since the mid 1950's, heart rate monitoring (HRM) instruments have advanced from pulse generators worn at the ear, to portable tape recorders, to HR distribution recorders. In the 1980's the first wireless, continuous HR monitor was developed.[22,64] The monitors are small, unobtrusive instruments that measure the electrical activity of the heart using a chest strap transmitter that sends electrocardiograph signals to a digital receiver watch with an internal clock.[123] Instrument refinements over the last 20 years have resulted in HR monitors that can record and store data in 15-second to one-minute epochs over several hours or several days, which can be downloaded to a computer.[35,38,64]

HRM is a relatively inexpensive and easy method for accurately assessing free-living PA and EE patterns.[3,21,32,33,35,36,38,40,61,65-70] Furthermore, HRM has important advantages over motion sensors.[27,65] Firstly, classifying PA intensity according to absolute cut points (i.e. moderate-intensity = 3-6 METs) provides limited validity among different age and fitness levels, as the perceived strenuousness of a given workload varies substantially,[27] and HRM provides an index of both relative and absolute PA intensity.[27,64] Secondly, HRM provides more accurate EE estimates, as the variation of error (-1.48, 1.56) is lower than that associated with motion sensors (-2.3, 2.3) to (-2.7, 3.8) METs.[27]

Individual Calibration Curves

Individual EE varies considerably[51] and is influenced by factors such as body mass, adiposity, age, gender, endurance capacity, fitness levels, dehydration and environmental conditions.[31,51,64,69,124] The accuracy of individual EE estimates is increased when the HR vs. $VO_2$ relationship has been determined.[35,61] The concept of individual calibration curves originates from the relationship between EE and HR.[32,36] HR and $VO_2$ are linearly related during dynamic work up to about 85% of $HR_{max}$, and particularly between 110 to 150 beats per minute (bpm).[33,38,65,68,125,126] Under controlled laboratory conditions, HR and $VO_2$ are measured simultaneously during rest and submaximal exercise at various intensities.[32,127] The individual HR vs. $VO_2$ calibration curves reflects EE by estimating the $VO_2$ associated with a given HR obtained during free-living activity.[35,40,46,64,69,125] Minute-by-minute HRM with individual calibration is a feasible technique for assessing the pattern and total level of free-living EE in medium-sized epidemiological studies.[60,61]

Limitations of Heart Rate Monitoring

However, assessing PA based on HR data has some inherent limitations that must be acknowledged:

- Established relationships between HR and AEE are lacking for many lifestyle activities.[35]
- The linear HR vs. $VO_2$ relationship applies to moderate-intensity activity but is nearly a flat slope during low-intensity activity,[128] resulting in a low correlation between HR and EE during sedentary and low-intensity activities.[127]
- Due to inter-individual variability HRM data is best applied to groups.[64,68,70,127,129-131] Individual 24-hour EE estimates have shown errors up to 30%, while estimates from group data usually fall within 10% of the true value.[32,35,68,125]
- Numerous confounding factors affect the HR response to PA and therefore the HR vs. $VO_2$ relationship.[127] These include high ambient temperature or humidity, time of day, emotional

state/stress, fatigue, hydration status, food, caffeine and nicotine intake, previous PA, illness, body position, mode of exercise and use of limbs.[32,33,35,38,53,64,119,132]

- Training status will also affect HRM data, as a less fit individual will elicit a higher HR than a more fit individual at any given $VO_2$.[21,38,53,116]
- Changes in work rates require a 3-5 minute adaptation period for the HR response to stabilise at that exercise intensity. Therefore, the exercise test protocol must allow sufficient time for the HR to reach steady state.[64]
- HR monitors are subject to electrical interference (i.e. computers, hairdryers, car engines, etc) which result in either spurious high or low values or momentary loss of data, and the affected data needs to be either removed or replaced by the mean of the surrounding HR values.[60,129]
- Habitual PA levels may be altered as the receiver watch continuously displays the current HR reading, and operating the receiver watch can become overly complicated for the average participant, as most monitors have advanced functions and settings designed for a serious athlete.[52]
- The chest straps are not well tolerated by individuals for time periods representative of daily life for 1 week or more.[32] Subjects become more aware of the chest strap after 4 days, which can occasionally come loose during normal daily activities,[62] and can cause skin irritations in some participants,[60,62] especially in hot weather.[60]

Alternative Heart Rate Monitoring Variables

Several methods exist for assessing HRM data, with the most appropriate technique being dependent on the research goals. The percentage of heart rate reserve (%HRR) method allows researchers to compare people with different fitness levels. Individual HR capacities are determined by measuring the difference between resting and $HR_{max}$.[69] Predetermined thresholds (%$HR_{max}$ or %HRR) are used to estimate time spent in activities of varying intensities, AEE, TEE, and PA levels.[32] Another technique, to compare activity between individuals of different fitness levels, is to subtract baseline HR from activity HR, but EE estimates cannot be determined using this method. Although the %HRR technique provides more accurate EE estimates, regression equations that include gender, body weight and age may also be used, as these variables all interact with HR.[132] That said, several calibration procedures to estimate EE from HRM data exist, including simple linear regression, log-linear regression, and two linear regressions.[133]

HRFlex Method

The HRFlex method was developed to limit the HR variability due to confounding factors, thereby improving the calibration procedure. This method uses two linear regressions to estimate EE from HRM data.[133] Towards the lower end of the HR vs. $VO_2$ calibration curve, the linearity is more variable. This threshold point is calculated as the mean of the highest HR while resting and the lowest HR during light-intensity activity.[32,46,60,69,116] The HRFlex point typically falls between 80 and 100 beats per minute,[126] and recorded HR values below the HRFlex point are analysed as resting EE.[32,60]

The HRFlex method provides researchers with an objective estimate of EE and PA patterns at a group level.[60] However, it is a time consuming and costly process and the validity and accuracy of this technique has been criticised for several reasons. Firstly, activities performed to establish HR vs. $VO_2$ calibration curves under controlled, laboratory conditions may not accurately reflect EE during free-living activities.[32,38,70] Also, the HRflex method assumes that one HR provides a physiological distinction between rest and exercise.[38] Currently, there is no consensus on defining and quantifying the HRFlex threshold, and different approaches exist.[70] However, Ekelund et al.[70] tested the accuracy and validity of TEE assessed by two existing HRFlex definitions and found only minor differences.

HRM + Motion Method

Haskell et al. (1993) proposed simultaneous collection of HR and motion sensor data in an effort to overcome their inherent limitations and obtain an accurate estimate of EE. The HRM + Motion technique involves the determination of separate HR vs. $VO_2$ regression equations for upper and lower body exercises performed in a laboratory setting.[51] The addition of one or more motion sensors increases HR vs. $VO_2$ correlations by up to 0.13 in individuals.[128] Motion sensors serve to verify that an elevated HR is due to PA, rather than a response to emotional stimuli,[32,52] and distinguish between upper and lower body activities. Meanwhile, HR data predicts $VO_2$ from the corresponding regression equation.[51] The increased accuracy of $VO_2$ predictions are observed during activities ranging from rest to vigorous intensities,[52,124,128,134] and the range of error (95% CI) is within ± 1.5 METs.[124]

Rennie et al.[52] were the first to develop and validate a one-piece instrument that collected HRM and motion sensor data simultaneously. This instrument was designed to have all the advantages of currently available HRM, as it is light, robust and waterproof, but is advantageous in that it evades electrical interference, is simpler to operate, and records in real time.[52] Preliminary results showed near perfect agreement with EE assessed by calorimetry.[32,52] However, there are currently no available one-piece instruments on the market.[32] Even so, Luke et al.[128] reported a minimum of 2 hours per subject was devoted to editing and checking data. The time required for individual calibration during multiple activities, as well as data management, limits the feasibility of this technique for epidemiological studies.[128,134]

### 2.5.3 Doubly-Labeled Water

The use of doubly-labeled water (DLW) to assess free-living EE in humans was first reported by Schoeller and van Santen,[32] and is currently regarded as the gold standard technique.[32,70] The DLW method involves the ingestion of a quantity of water labeled with a known concentration of naturally occurring, stable isotopes of hydrogen ($^2H$) and oxygen ($^{18}O$). The isotopes mix with the normal $^2H$ and $^{18}O$ in the body water within a few hours, and as energy is expended in the body, carbon dioxide ($CO_2$) and water are produced.[32] The difference between the isotope elimination rates reflects the rates of $CO_2$ production and $O_2$ consumption, which are used to calculate TEE.[32,36,135]

Although several assumptions and sources of error are associated with the DLW method,[22] this technique provides the most accurate measure of free-living TEE with a reported precision of ± 3%,[129] and serves as a reference for validating other methods.[32] DLW can be carried out on a wide range of individuals over lengthy time periods, usually between 4-21 days, which is advantageous for capturing habitual EE patterns.[32]

However, data pertaining to PA patterns or energy costs of activities are not acquired.[32,33,53] Calculating the energy cost of activity involves subtracting EE due to food, rest, and perhaps growth, from TEE, which increases the error involved and decreases any advantage DLW has over other methods for assessing PA.[136] Furthermore, the cost of the materials and expertise required to analyse the isotope concentrations via mass spectrometry prohibits the use of DLW in large epidemiological studies.[32,35,46,52]

### 2.5.4 Calorimetry

Direct Calorimetry

Direct, whole-room calorimetry directly measures the body's heat production to gauge the rate and quantity of EE production.[3] An individual is confined to a room calorimeter, a thermally-isolated chamber, which allows the subjects to perform nearly free-living activities while measuring all expired gases,[46] body heat dissipated by evaporation, radiation, conduction and convection,[32] EE and accelerations on a minute-by-minute basis.[57] This is a non-invasive technique which provides data with excellent accuracy and precision, although on 'near' free-living activity.[137] The number of free-living activities that can be performed in the confines of one room is limited.[32,33,46] Whole-room calorimetry is a technically complex, expensive and time consuming procedure,[32] as it requires calibration checks and only one individual can be monitored at one time. Additionally, this method is inconvenient and intrusive for the subjects involved, as well as for researchers as the equipment is not transportable.[137]

Indirect Calorimetry

Indirect calorimetry is a technique which provides accurate estimates of EE from measures of $CO_2$ production and $O_2$ consumption during rest and steady-state exercise.[32,137] When 'external work' is performed, the rate of heat production is equivalent to the rate of heat lost, plus the amount of external work performed.[137] There are open- and closed-circuit methods, and technology has advanced from the Douglas Bag method to fully portable, electronic equipment that provides continual and instantaneous breath-by-breath values of pulmonary gas exchange. The Metamax and Cosmed K4b2 are two newer portable systems that have been validated and found to provide good accuracy and reliability.[32] There are numerous advantages involved with indirect calorimetry[32,137]:

- Measures human performance during any type of free-living activity
- Good accuracy
- Good to excellent precision
- Acceptable cost
- Fast response time
- Relatively easy and fast calibration checks
- Good acceptability, non-invasive and convenient for subjects
- Useful for validating other methods

- Fully transportable
- Capable of assessing cardiopulmonary limitations, applicable in clinical studies

Indirect calorimetry is carried out on an individual basis, which makes this a fairly time-consuming process ideal for smaller studies.[32] Continuous gas exchange measures are normally limited to 1-5 hours, although when used for the purpose of individual calibration during HRM, the required time is generally less than one hour for resting and exercise measures (depending on the number of activities involved in creating the calibration curve). Furthermore, there is a fair level of technical complexity,[137] and EE estimates are only valid for activities in which steady-state is achieved.[32]

### 2.5.5 New Approaches to Assess Free-living Physical Activity

The ability to accurately assess PA in free-living individuals continues to be a challenge, as each method has inherent limitations. Researchers are currently working to develop new instruments and approaches to provide valid and reliable EE estimates for a wide range of individuals, activities and settings.[34,35,118,138]

Differential Satellite Global Positioning System

Differential satellite global positioning system (DGPS) is a new approach to measuring locomotion (walking and/or running) pattern, utilizing a satellite-based navigation system to broadcast radio frequency signals, each modulated with a unique code sequence and navigation data message.[35] The receiver, worn by the subject, decodes the signals, measures travel time between the satellite and the navigation set and the rate of change to calculate the velocity of displacement[118] and provide a proxy measure of the intensity of locomotion, even during slow walking.[35] DGPS measurements provide continuous, all weather, three-dimensional position, velocity and time with excellent accuracy. This method can be applied to any individual, walking or running on any terrain, even at slow speeds, for prolonged time periods and unlimited distances, which is not currently possible with other instruments. Additionally, DGPS is totally independent of an exterior investigator, as data pertaining to locomotive activity (the most common free-living activity) performed in a natural setting, can be visualized on-line (using Doppler shift).[118]

The only downfall associated with DGPS is that speed measurements are impossible while inside a house or underwater, and obstacles such as urban canyons, tall skyscrapers, tunnels, caves, and compact trees impede access to the satellites. However, research using DGPS is extremely limited, and further technical developments are required to compact the equipment into a single portable unit.[118]

Arm Band

The SenseWear Pro Armband™ is a commercially-available, portable instrument that is worn over the triceps muscle on the right upper arm. This device measures acceleration combined with physiological parameters such as heat flux, galvanic skin response, skin temperature and near-body temperature. Demographic information and data from the above parameters are applied to proprietary equations to calculate EE, and exercise-specific algorithms provide better estimates. Preliminary testing of the Armband™ carried out in a laboratory found nonsignificant differences to estimates from indirect calorimetry.[138] However, independent validation across a variety of free-living activities is needed.

### 2.5.6 Summary – Which Method to Use When?

It is evident that no single instrument can accurately assess all aspects of free-living PA in a wide range of populations, settings, and uses.[33-35] Direct observation, indirect calorimetry, and doubly-labeled water methods are primarily useful in validation studies rather than field research.[139] The various factors to be considered in the selection of PA methods include experimental goals, type and duration of activity, the main dimension of PA that is of health interest, sample size/size of study, frame of reference (e.g. current activity or past activity), budget/expense, cultural, social, and environmental factors, physical burden for the subject, and statistical factors such as accuracy and precision.[32,35,36] For some biological end-points such as obesity or obesity-related diseases like diabetes, measurement of the pattern and total level of EE is an important consideration. By contrast, for end points like osteoporosis, assessment of participation in weight-bearing activity would be more relevant.[60]

Physical activity sensors which are of low-cost, small-sized, and convenient for subjects, investigators, and clinicians, are needed to reliably monitor, during extended periods in free-living situation, small changes in movements and grade as well as duration and intensity of typical PAs.[33,35] Efforts should be directed toward developing an objective motion sensor as inexpensive as a pedometer, but with the data acquisition capabilities of advanced accelerometers. In the meantime, complementary methods are required to obtain a more accurate profile,[34,35,140] and additional studies are needed to examine the possibility of improving the accuracy of measurement by combining two or more techniques.[32] The objective method of choice depends on how the measurement will be used, whether for surveillance or epidemiological studies, and what type of data is required (Table 6).[33,35,38,60] Table 7 illustrates the advantages and disadvantages of each method.[3]

**Table 6.** Physical Activity Assessment Methods

| **Purpose** | **Requirements** | **Appropriate Methods** |
|---|---|---|
| Energy balance, metabolism, weight loss | Precise and quantitative measurement of TEE | DLW, direct calorimetry |
| Validation of questionnaires or studying activity patterns | Measurement of PA duration, frequency, intensity, EE | Accelerometers, HRM, or a combination of both techniques |
| Epidemiological studies | Inexpensive, easy to use equipment to assess PA levels and patterns in populations | Electronic pedometer |

**Table 7.** Comparison of Measurement Instruments for Adult Physical Activity

| | | Study Costs | | Subject Costs | | | |
|---|---|---|---|---|---|---|---|
| **Measurement Instrument** | **Use in large studies** | **Low cost** | **Low Time** | **Low time** | **Low effort** | **Unlikely to Influence behaviour** | **Activity Specific** |
| Recall PAQ | Y | Y | Y | Y | Y | Y | Y |
| Global PAQ | Y | Y | Y | Y | Y | Y | N |
| Activity Diary | Y | Y | Y | N | N | N | Y |
| Pedometer | Y | Y | Y | Y | Y | Y | N |
| Accelerometer | N | N | N | Y | Y | Y | N |
| HRM | N | N | N | Y | Y | Y | N |
| HRM + Motion | N | N | N | Y | Y | Y | N |
| DLW | N | N | N | Y | Y | Y | N |
| Direct Calorimetry | N | N | N | N | N | N | Y |
| Indirect Calorimetry | N | N | N | N | N | N | Y |

PAQ = Physical Activity Questionnaire, HRM = Heart Rate Monitoring, DLW = Doubly-labeled water
Y = yes, N = No

## 2.6 THE NATURE OF PHYSICAL ACTIVITY: VARIATION

Physical activity is a complex, multidimensional behaviour difficult to assess accurately due to the substantial variation that occurs within and between individuals and populations.[49,141] Long-term patterns of usual PA, although often relatively constant, can be influenced by physiological factors such as changes in body weight or composition, state of training, illness, or ageing. Short-term, daily patterns are often influenced by factors beyond one's control such as minor infection or personal injury, insufficient sleep, environmental temperature, emotion, consumption of alcohol, caffeine, tobacco or food, and cultural or ecological factors such as day of the week, weekday vs. weekend day, or current season.[68,139,142] Daily variation in PA is one of the three sources contributing to the variance of PA measures, which include measurement error, between- and within-person variation.[90]

### 2.6.1 Definitions of Related Terms

- **Within-person Variation:** Also referred to as 'Intra-Individual Variation', this value represents random temporal fluctuations around an individual's long-term average value when measured repeatedly by a valid, error-free measurement instrument.[90,142,143]

- **Between-person Variation:** Also referred to as 'Inter-Individual Variation'. It is assumed that each individual in the population has a fixed but unknown constant value for the measurement which is appropriate to them (i.e. usual or habitual PA level). This value reflects the population variance of the true mean differences, which cannot be measured without error, between individuals.[90,143] This source of variation is most important when calculating sample size and power.[90]

- **Measurement Error:** Measurement error is the difference between the observed value and the corresponding true but unknown value, and can contribute to within-person variance of measured values.[90]

### 2.6.2 Effects of Variation on Physical Activity Measures

Research assessing habitual or usual PA patterns in free-living populations must account for the possibility that variation substantially reduces statistical associations.[94,142] Studies examining individual, daily and seasonal variations in PA levels are briefly reviewed below.[60,68,94,127,142,143]

Individual Variation of Physical Activity

Levin et al.[94] examined seasonal and individual variation in 77 adults over a 12-month period, in an effort to determine the optimal number of repeated measures needed to reliably measure an individual's usual PA habits. PA was assessed by 48-hour accelerometer counts and PA records every 26 days (14 measures), as well as four-week histories (FWH). Each instrument associated higher PA levels with warmer months, and substantial levels of intra-individual variation, accounting for 60% (accelerometer) to 70% (PA records) of variance. The coefficient of variation (SD as % of mean annual PA level) for accelerometers, PA records and FWH was 9%, 11%, and 39%, respectively. The authors concluded that usual PA over a one-year period can be accurately assessed with 6 accelerometry measures, 9 measures of PA records, or 3 administrations of the FWH.

Matthews et al.[143] aimed to identify and estimate daily PA variance in a sample of 92 individuals aged 18-79 yrs. Subjects wore hip-mounted accelerometers for 3 weeks, and provided occupational and LTPA information via weekly telephone interviews. Inter-individual variation was the largest contributor to total variance (55-60%), followed by intra-individual variation (30-45%) and day of the week (1-8%). In contrast, intra-individual variability was responsible for the majority of variance for time spent in physical inactivity (55-57%). The authors concluded that acceptable and reliable data on PA and inactivity could be obtained from 3-4 and 7+ days of monitoring, respectively.

Several studies have compared the effects of individual variation obtained from HRM as well as the gold standard methods. Kalkwarf et al.[130] compared 4 days of EE assessed by HRM ($HRM_{EE}$) to EE assessed by calorimetry ($CAL_{EE}$) in 12 females aged 19-27 years and found an overestimation of 2-9%, while Spurr et al.[126] reported a variation of -15% to +20% between $HRM_{EE}$ and $CAL_{EE}$. A study by Heini et al.[144] measured direct $CAL_{EE}$, $HRM_{EE}$, and EE assessed by DLW ($DLW_{EE}$) over 2-3 days in 8 males and found individual EE discrepancies ranging from 5.2% to 17.4% between the three methods, and TEE from HRM alone ranged from 3004–5347 kcals/day. In a study comparing 2 EE estimates from the HRFlex method ($HRFlex_{EE}$) to $DLW_{EE}$ in 8 males,[70] individual discrepancies ranged from -11% to +24%. Similarly, Davidson et al.[129] noted errors up to 20% for individual $HRM_{EE}$ estimates compared to direct $CAL_{EE}$ estimates in 9 males.

Weekday vs. Weekend Variation of Physical Activity

Results for weekday vs. weekend variation are conflicting. Data from 92 subjects reported an average of 30-45 minutes per day greater activity during the weekend compared to weekdays, with Saturday being the most active day for both men and women (~25 minutes greater than Sunday).[143] In contrast, Wareham et al.[60] examined weekday vs. weekend bias in 97 subjects and reported mean PA levels of 1.8144 ± 0.37 and 1.8135 ± 0.384, respectively. A paired t-test comparison resulted in a t-value of 0.03 and the mean paired difference for weekday vs. weekend was 0.0008 (95% CI = -0.060 – 0.061). Thus, further research is required to determine whether daily PA is higher on the weekend or during the week, and whether they are related to each other.

## 2.7 MEASURING PHYSICAL ACTIVITY: STATISTICAL CONCEPTS

### 2.7.1 Validity of Physical Activity Assessments

Validity indicates the degree of accuracy that an instrument measures what it is supposed to measure.[36] The multidimensional nature of PA, the lack of clear, consistent definitions, and using terms interchangeably exacerbates the problem of obtaining valid measures of this behaviour.[36,42,46,53] Current PA recommendations state that, on at least 5 days/week, individuals should engage in a minimum of 30 minutes of at least moderate-intensity PA to obtain health benefits. Therefore, PA surveillance instruments are expected to produce estimates of PA patterns (frequency, duration, intensity) in relation to current PA recommendations.[42] That said, a valid instrument should provide valid scores for each PA dimension and all contexts in which activity is performed,[6,8,42] making it possible to[6,46]:

- Define a population PA level
- Ascertain how people achieve their PA
- Make cross-cultural comparisons
- Estimate more accurately the effect size
- Monitor temporal trends in PA
- Monitor the effect of interventions
- Specify which aspect of PA is important for a particular health outcome
- Identify the target audience to promote the adoption and maintenance of PA

Often, investigators have accepted correlation coefficients for validity of 0.3-0.5 relative to other direct or indirect measure of PA and EE.[29] Validity has a number of facets (content, criterion and construct).

<u>Content Validity</u>

Content validity, also referred to as 'face validity' or 'logical validity', refers to the degree to which an instrument represents a specified domain.[65,145] In PA research, content validity relates to an instrument's ability to assess the full range of PA characteristics, producing estimates related to public health guidelines (i.e., sedentary, moderate, vigorous activities) and obtaining data for all dimensions and contexts of activity.[42]

Criterion Validity

The purpose of establishing criterion validity is to determine how well the obtained measures correlate with those from the objective, more precise assessment. There are two types of criterion validity: concurrent validity and predictive validity.[65]

- Concurrent Validity: Represents the correlation of an instrument with some criterion that is administered concurrently.
- Predictive Validity: The degree to which scores of predictor variables can accurately predict criterion scores.

In regard to PA measures, confounding factors and lack of validation in all types of activities across all age and ethnic groups imply a lack of true criterion measures of PA. DLW, although the most accurate measure of TEE, does not allow information about frequency or intensity.[53] Consequently, reliance has usually been placed on construct validation against other observations that are linked with PA.

Construct Validity

Construct validity is the degree to which a test measures a latent variable or theoretical concept (construct) which is not directly measurable, such as usual PA or health, and is usually established by relating the test results to some behaviour.[65,145] The first and most important step in construct validation is to define the targeted construct, in this case, PA.[53] EE measures using DLW are commonly accepted as the optimum in construct validation. Other approaches to validation have included comparisons with information obtained from HRM, PA Logs or diaries, 24-hour PA recalls, fitness scores, etc. Significant correlations with CRF should be observed only for vigorous-intensity PA, as correlation coefficients have been largest for the most intense forms of activity.[29]

### 2.7.2 Reliability

Reliability is the consistency of agreement in a measure between results obtained by different approaches (i.e., different observers, study instruments, or procedures) or by the same approach on different occasions.[146] Ideally, the only source of variability in a study would be that between study participants. However, the reliability of a measured value is decreased when many sources of variability are present, including imprecise cognitive processing, memory errors, seasonal or temporal variations in PA over time, measurement error, and individual physiological or behavioural differences.[42,50,146] Therefore, an instrument cannot be considered valid if it is not reliable.[145]

Many variables can affect the accuracy and interpretation of reliability estimates, such as sample size and characteristics, instrument recall period and time periods between tests, the number of trials and how the reliability coefficients are reported. Common deficiencies found in PA research studies which assess reliability have been identified.[42,53,147] Patterson[53] proposed the following solutions related to the study protocol and reporting of results in an effort to improve the quality and comparability of such research:

1. Reliability studies unnecessarily report the level of significance when the value of the correlation coefficient is the primary concern. Additionally, significance testing of reliability coefficients is irrelevant.
2. 95% confidence intervals are not commonly reported for reliability estimates, but should be, as they indicate the precision around the estimate, which is especially helpful with varying sample sizes.
3. Single trial reliability estimates are associated with inflated coefficient values. Published literature should acknowledge this when it pertains to the particular study. To avoid this, test-retests should be performed to detect significance across days.
4. Test-retest studies are also needed to establish internal consistency of self-report instruments to assess the reliability of the instrument itself and its components (i.e. frequency, duration, intensity) when administered on a single day. The ability to identify which aspects are easy or difficult to recall is necessary for instrument refinement. For example, activity intensity is the most poorly recalled dimension of PA.
5. Reliability estimates should be included and reported for subgroups, as the range of activity scores are wider with group estimates, which lead to inflated estimates. Additionally, sample populations with a high proportion of sedentary or inactive participants will also produce inflated reliability indices.[147]
6. The instrument's recall period and the time interval between trials also affect reliability estimates. Repeatability measures must cover the same time period as the initial test (i.e., one day recalls should be repeated on the same day, and one week recalls should be repeated within one week), although recall instruments assessing 'usual' PA should be less sensitive to this concept.[42]

### 2.7.3 Validity and Reliability Indices for Continuous Data

Spearman Correlation Coefficient

Spearman correlation coefficient (r or ρ), also referred to as ordinal or rank correlation coefficient, classifies subjects using the distribution of study values. This coefficient takes the value of +1 when the ranks are exactly in the same order, a value of -1 when the ranks are exactly in an inverse order, and a value of zero when there is no association between the ordering of the two sets of paired values.[65]

Bland-Altman Plots

The use of the mean and standard deviation of the difference between two measures has been strongly advocated by Bland and Altman[148] to graphically illustrate the magnitude and pattern of disagreement (including systematic differences), and allow for detection of outliers. Furthermore, between-person variance does not affect the standard deviation values.[142] Data are presented as a scatter plot where the x- and y-axes represent the mean value and the difference between the paired measurements, respectively. If one measure is considered the gold standard, it is acceptable for mean values measured by the gold standard, to be depicted on the x-axis.[142] The vertical departure from zero will represent the magnitude of bias of the test value with respect to the gold standard.[146]

Simple Linear Prediction

Simple linear prediction, also referred to as regression, is a statistical method used to predict the criterion, outcome, or dependent variable, $Y$, from a single predictor or independent variable, $X$. If two variables are correlated, a prediction equation can be computed in the form of $Y = bX + c$, where b is the slope of the line, indicating how much $Y$ changes for a unit change in $X$.[65] Residual scores reflect the lack of fit, or error (E), involved in the prediction equation, and can be quantified by $E = Y - Y'$, where $Y$ is the measured value and $Y'$ is the predicted value.[65]

### 2.7.4 Validity and Reliability Indices for Categorical Data

Weighted Kappa

The Kappa statistic (κ) is an improvement over 'percent agreement', as agreement expected on the basis of chance alone is discounted.[142] This statistic estimates the reliability between two measures, accounts and corrects for agreement expected to occur purely by chance. Defined as the proportion of the observed agreement not due to chance in relation to the maximum non-chance agreement, possible values of κ range from -1 to 1.[146]

When study results can be expressed by more than two categories, certain types of disagreement may be more serious than others. In this situation, different levels of disagreement can be 'weighted' to assume that they represent some sort of 'partial' agreement, where more weight is assigned to less extreme disagreements.[146] However, using the kappa statistic to compare ordinal/continuous data is discouraged, as the number of categories influences the kappa value and its interpretation.[142] Additionally, differences in prevalence of 'true positivity' in different populations affects κ values, so it is therefore recommended that κ be used in conjunction with other measures of agreement.[146]

## 2.8 COMPARISON OF STUDIES

The following section reviews several studies which have used the HRM technique to assess free-living PA levels and patterns in adults. The validation studies in this section are described in detail since they cover the main topics of this thesis. Specific search topics included validation of HRM to gold standard methods, individual calibration and variation, and HRM to validate PAQs.

### 2.8.1 Literature Search Strategy

Computerised searches were performed on Entrez PubMed to identify literature involving the HRM technique to measure adult PA levels. The searches covered literature published between 1985 and 2004, and were performed using the following phrases and combinations:

- Objective monitoring of physical activity levels
- Heart rate monitoring to assess physical activity
- Heart rate monitoring AND physical activity levels
- Energy expenditure AND heart rate monitoring
- Individual calibration AND heart rate monitoring
- Heart rate variability AND physical activity
- Validation of physical activity questionnaires

References identified by the above searches were used to locate related articles overlooked by initial computer searches. The following inclusion and exclusion criteria were applied:

- Only papers written in the English language were included
- Only studies of adult humans were included
- Studies were excluded if the sample population included pregnant women or individuals diagnosed with chronic diseases or conditions.

### 2.8.2 Heart Rate Monitoring vs. Gold Standard Techniques

Epidemiological studies must often compromise between accuracy, cost and participant burden when assessing PA levels. The expense and invasiveness of highly accurate, objective methods prohibits their use in large-scale studies, and PAQs aiming to capture all PA dimensions and contexts are often too lengthy and time-consuming. As a result, methods that are cheaper, quicker, and pose less participant burden are generally utilized, although the measurement error may be increased.[146]

DLW and whole-body, indirect calorimetry produce accurate and precise EE estimates in individuals and serve as the gold standard methods to assess the validity of other measurement techniques.[32,46,68,70,129-131,144] The use of these gold standard techniques is generally avoided in population studies due to associated expenses and participant burden. More feasible approaches to PA assessment are possible with alternative methods, which should be objective and demonstrate high correlations with gold standard methods.[36]

A comprehensive search and review was conducted on studies comparing HRM and HRFlex methods (Tables 8 and 9, respectively) to DLW and calorimetry for assessing PA levels or patterns in healthy adults. The 16 studies reviewed were carried out between 1988 and 2003, with sample sizes ranging from 8 to 789 participants, and HRM periods ranging from a few hours to 9 consecutive days.

Heart Rate Monitoring vs. Doubly-Labeled Water and Calorimetry

Eight studies have compared $HRM_{EE}$ to $DLW_{EE}$ and/or $CAL_{EE}$.[27,63,68,129-131,133,144,149] Table 8 contains a summary of the design and results from these studies. Davidson et al.[129] compared 9 days of $HRM_{EE}$ to $DLW_{EE}$ in 9 males aged 25-54 years and found that accuracy of $HRM_{EE}$ estimates could be improved by 10% (from +16.3%, SEM 4.9 to +6.0%, SEM 4.2) by removing spurious values and inserting missing values. Kashiwazaki[133] monitored 10 subjects and reported a mean difference of -3.1% (-35.1% to +36.6%) for $DLW_{EE}$ vs. 24-hr $HRM_{EE}$ using the log-linear calibration procedure. Strath et al.[27] compared $HRM_{EE}$ and $CAL_{EE}$, and reported a correlation of r=0.87 (SEE = 0.76 METs), after adjusting for age and fitness level, indicating HRM to be a strong predictor of EE.

Accurate $HRM_{EE}$ estimates have also been obtained for groups of older adults. Studies by Morio et al.[131] and Rutgers et al.[149] assessed 3-4 days of $HRM_{EE}$ in small samples (N = 12 and N = 13, respectively) of elderly individuals. Calibration curves were generated from a variety of low- to moderate-intensity activities using indirect calorimetry. Morio et al.[131] reported mean differences between $HRM_{EE}$ and $DLW_{EE}$ of +4.5% (SD = 14.4%) for men and +5.9% (SD = 8.8%) for women, and -0.1% (SD = 5.8%) when compared to indirect $CAL_{EE}$.[131] Rutgers et al.[149] also reported nonsignificant differences between mean $HRM_{EE}$, $DLW_{EE}$, and $CAL_{EE}$. Results from $HRM_{EE}$ vs. $DLW_{EE}$ studies are similar. Overall, these studies indicate that HRM is an accurate technique for assessing adult, free-living EE at a group level.

HRFlex vs. Doubly-Labeled Water and Calorimetry

The HRFlex method, which involves an improved calibration procedure,[133] has also been reported to produce $HRFlex_{EE}$ estimates comparable to the gold standard measures (Table 9).[60-63,70,126] Compared to $CAL_{EE}$, Ceesay et al.[63] reported a nonsignificant underestimate of 24-hour $HRFlex_{EE}$ (mean error = 0.6%, mean difference = -1.2 ± 6.2%, SEM = 1.4). Similar comparisons were made by Spurr et al.[126] and Rennie et al.,[61] who reported correlations of r=0.92 (mean difference = +2.7 ± 9.2%, SEM = 2.0) and r=0.93 (p<0.001) between the two methods, respectively. Combined results from Spurr et al.[126] and Wareham & Rennie[46] provided a correlation coefficient of 0.96 with a mean error of 0.6%.

$HRFlex_{EE}$ was compared to $DLW_{EE}$ by Wareham et al.[60] over 4 days of HRM in 164 subjects aged 30-40 years. A strong, negative relationship between TEE and time spent below the HRFlex point was observed in men and women (p<0.001), as well as a positive relationship between TEE and time spent at higher EE levels (p<0.001). Heini et al.[144] compared $HRM_{EE}$ and $DLW_{EE}$ in 8 males aged 25 ± 4 years, and reported a nonsignificant mean difference of 314 kcals/day, between both methods. An overestimate of +9.3% (SEM = 4.2) was reported by Davidson et al.[129] when filtered $HRFlex_{EE}$ data from 9 males was compared to $DLW_{EE}$. Livingstone[62] reported a slight overestimate in $HRFlex_{EE}$ in 14 subjects (+2.0 ± 17.9%), compared to $DLW_{EE}$, and found overestimates in males (+5.3 ± 20.6%) and underestimates in females (-4.0 ± 11.5%). Ekelund et al.[70] compared TEE measured by DLW and 2 HRFlex definitions in 8 young athletes (mean age = 18.2 years) over two different training periods of 8-10 days. Significant differences existed for time spent above the predetermined HR threshold (p=0.004) and $HRFlex_{EE}$ (p<0.001) computed with the different HRFlex definitions. However, no significant differences were observed between the three methods (p=0.44) or training periods (p=0.83).

Quantifying EE in individuals who participate in little or no PA remains a challenge due to inter- and intra-individual variation and the low predictive power around the HRflex point.[38] However, using HR variables such as %HRR or net HR ($HR_{net}$) (activity HR – resting HR), which adjust for individual age and fitness levels, provides more accurate EE predictions.[27,69] Strath et al.[27] reported a correlation of r=0.87 (SEE = 0.76 METs, mean error = 0.04 METs, 95% CI of error score = (-1.48, 1.56).

### 2.8.3 Variability of Heart Rate

HR is a physiological parameter that corresponds well with EE, and reproducibility within subjects is high, with test-retest correlations of 0.872 ± 0.03 and coefficients of variation around 1.6 ± 1.3%.[27,64]

However, random fluctuations within and between individuals, due to several short- and long-term factors, can substantially reduce the strength of associations and therefore the accuracy of EE predictions.[27,64,68,130,131,133,142,144,149] Activities performed at submaximal and maximal intensities have produced average intra-individual variations of 4.1% and 1.6%, respectively, and a daily variation of 3 bpm was reported for maximal HR.[64] The impact of individual HR variation on $HRM_{EE}$ can be high, especially if activities are performed over several hours,[130] or in individuals with low PA levels.[149]

Intra- and inter-individual variations of $HRM_{EE}$ in 40 females, aged 20-45 years, over 16 hours, ranged from 10.6% to 20.4% and 14.1% to 17.6%, respectively.[68] A larger study by Strath et al.[27] examined the HR vs. $VO_2$ relationship in 61 subjects (31 males, 30 females) aged 19-74 years during moderate-intensity activities performed in field and laboratory settings, and found HR accounted for 47% (SEE=18.23 $ml \cdot kg^{-1} \cdot min^{-1}$) and 78% (SEE=0.76 METS) of the variability in $VO_2$ and measured $HRM_{EE}$, respectively. The error around $HRFlex_{EE}$ estimates is similar, ranging between -15% to +52%.[62,63,126]

HRM may not be an appropriate technique for assessing EE in elderly populations due to the large daily variation in HR, as reported by Rutgers et al.[149] and Morio et al.[131] $HRM_{EE}$ measured over 4 days in 12 elderly individuals produced intra-individual variations of 11.6% (SD=7.6%) and 7.6% (SD=4.2%) for men and women, respectively. This variation is also evident in indirect $CAL_{EE}$, where low- to moderate-intensity activities performed by elderly individuals over 3 days varied by 7.6%, and a variation of 6.3% was observed during walking activities.[131]

### 2.8.4 Individual Calibration Curves

The effects of individual variation associated with $HRM_{EE}$ is minimised when individual calibration curves are generated.[68] A general description of this procedure, involving simultaneous measures of HR and $VO_2$ in a laboratory setting,[68,149] is provided in Section 2.5.2. Individual HR vs. $VO_2$ curves facilitate interpretations of HR data by providing the associated EE and intensity level (METs) of free-living PAs performed during HRM.[61]

Although Strath et al.[27] reported moderate correlations between HR and $VO_2$ in laboratory and field settings (r=0.68, SEE = 18.23 $ml \cdot kg^{-1} \cdot min^{-1}$), calibration curves have demonstrated high reliability with a mean difference of only -124 ± 1431 kJ/16 hours for test-retest correlations, and a squared multiple correlation coefficient ($R^2$) of 0.91 ± 0.06, $p<0.001$. An ideal calibration procedure should include several PAs representing normal daily living, and involve upper and lower limb movement over a wide range of intensities to increase $HRM_{EE}$ accuracy.[68] To minimise HR responses from stimuli other than PA, each subject must also adhere to specific instructions prior to individual calibration. HR readings can differ by 2-4 bpm when individuals are assessed on different days, even in a controlled, laboratory setting.[64] It is therefore advised that individual calibration be repeated on different occasions if long-term EE estimates are required, even for the same individual.[68] Consequently, determining individual HR vs. $VO_2$ relationships is time consuming for researchers and participants, and has limited practicality for large, epidemiological studies.[61,68]

In an effort to expedite $HRM_{EE}$ measurement and analysis for population studies, Rennie et al.[61] investigated the feasibility of HRM without individual calibration. The researchers derived calibration parameter predictions during rest and an exercise test on a cycle ergometer, and found a significant correlation between estimated and measured values, with 98% of the sample placed in the same or adjacent quartile.[61]

Individual vs. Group Estimates

Individual $HRM_{EE}$ can be accurately estimated when a subject undergoes the calibration curve process, although the need for repeated measures in long-term studies, even in the same individual, is suggested.[68] The higher error around the true value of $HRM_{EE}$ derived from individual calibration curves (up to 30%) compared to group calibration curves (usually ± 10%) has been well established.[35,68,130,131,133,149] In an effort to determine whether a single calibration equation, generated from 18 different activities, could be used for all subjects, Li et al.[68] randomly divided 40 subjects into 2 groups. Results showed poor agreement between group and individual calibration curves. Rutgers et al.[149] found correlation coefficients for individual and group calibration curves of $r=0.89 \pm 0.10$ and $r=0.93$, $p<0.02$, respectively, using 5 low- to moderate-intensity PAs performed by 13 elderly females. Furthermore, 3-day TEE estimates from individual and group calibration curves were not significantly correlated ($r=0.37$).[149]

Variability of the HR vs. $VO_2$ Relationship

The HR vs. $VO_2$ relationship can be affected by an individual's age, gender and training status,[27] and within-day variability of the HR vs. $VO_2$ relationship could influence the error associated with individual calibration.[127] McCrory et al.[127] examined the influence of within- and between-day variability of the HR vs. $VO_2$ relationship on 24-hour EE estimates. Twelve subjects (6 male, 6 female) underwent individual calibration during rest in various positions and 8 calibration activities. Although no between-day group differences were observed, within-day data revealed significantly higher resting $VO_2$ values assessed in the afternoon compared to the morning. EE calculated by four different regression equations revealed low levels of intra-individual variability, comparable to gold standard techniques. The data also showed excellent average between-day and within-day repeatability of the HR vs. $VO_2$ relationship.

However, daily HR can vary considerably while $VO_2$ generally remains stable across a range of submaximal workloads.[22] Correlations between HR and $VO_2$ during lower-intensity activities were weak, resulting in higher intra-individual variability in $HRM_{EE}$ for sedentary individuals because the majority of their daily activity elicits low HR responses.[127] Furthermore, other individuals may demonstrate highly unpredictable variability for other reasons.

Increasing the Accuracy of Individual Calibrations

Increasing the number of calibration activities that mimic normal daily activities has been recommended to improve the accuracy of $HRM_{EE}$.[68,70] However, Ekelund et al.[70] reported walking, running, and bicycling activities performed in the laboratory represented free-living activities carried out during two training periods consisting of different types, durations and intensities of activities not included in calibration activities, at least on a group level.

Strath et al.[27] reported more accurate $HRM_{EE}$ predictions (r=0.87, SEE = 0.76 METs) when individual age and fitness levels are accounted for in regression equations. Expressing data as %HRR resulted in a mean error of 0.04 METs, 95%CI = (-1.48, 1.56) METs, over a wide range of lifestyle PAs at varying intensities. Hiilloskorpi et al.[69] developed different EE prediction equation models using HR, HRR, and $HR_{net}$. Results showed equations using HRR (SEE = 1.01 kcal/min or 4.22 kJ) or $HR_{net}$ (SEE = 1.08 kcals/min or 4.51 kJ) have higher predictive values compared to HR data that does not account for individual differences in age and fitness levels. Other individual factors such as body weight and sex also remain valuable factors in EE prediction equations.[69]

### 2.8.5 Other Influencing Factors to Heart Rate Monitoring

Sample Size

Studies involving validation of HRM to measure EE generally have small sample sizes due to the expense, burden, and time required for individual calibration and data analyses. Studies with small sample sizes have limited power to detect differences between the test method and gold standard. The majority of studies assessing free-living EE have reported results for relatively small sample sizes (N=8 to N=40) within a small age range, and have excluded one gender.[68,129-131,144,149] Somewhat larger studies with wider age ranges, involving both males and females, have been published by Strath et al.[27] (N=61, 19-74 years), Hiiloskorpi et al.[69] (N=89, 19-53 years), and Rennie et al.[61] (N=97, 30-40 yrs), with the largest HRM study conducted by Wareham et al.[60], which involved 164 subjects aged 30-40 years. These larger studies with higher power have found good agreement between HRM and gold standard methods.

Number of Days of Heart Rate Monitoring

Studies employing HRM as the objective measure of PA have collected HR data over periods ranging from 16 hours to 9 days. Although collecting individual data over multiple days will dramatically improve estimates, the numbers of days required in some cases would impose a high participant burden.[139] Rennie & Wareham[36] reanalysed data from a previous study[60] to examine the measurement period required to elicit valid EE estimates. EE assessed from two adjacent days of HRM produced a correlation coefficient of r=0.65 and a validity coefficient of 0.79. A third and fourth day of HRM yielded coefficients of 0.85 and 0.88, respectively. Issues such as participant behaviour and comfort must be considered when deciding how many days of HRM are needed, as HR monitors are not well tolerated by individuals for time periods of 1 week or more,[32,36] although a 4-day HRM period was reported as the turning point at which subjects became more aware and less tolerant of the chest strap.[60] Another concern with long HRM periods is that participant behaviour could be affected.[139] Although the HRM period will ultimately be determined by factors such as expense and participant cooperation,[36] the number of measurement days required is also influenced by variation and the desired level of accuracy, and standard equations can be utilised to determine an adequate assessment period.[60,120,142]

Gretebeck & Montoye[120] investigated the measurement period required to minimise intra-individual (within-person) variation and produce reliable PA estimates with less than 5% error. Activity levels of 30 males aged 24-67 years were objectively measured over 7 consecutive days using 2 pedometers, 3 accelerometers and one HR monitor. The researchers concluded a period of 5-6 measurement days were required to sufficiently minimise intra-individual variation. A second purpose of this study was to examine differences between weekdays and weekend days. HR data from weekends increased between-person variance more than within-person variance, as the mean HR correlation for 7 days (r=0.62) increased when weekend days were excluded (r=0.76) and decreased when weekdays were compared to weekend days (r=0.50). The authors suggested HR data from both weekdays and weekend days should be collected. However, Wareham et al.[60] compared weekday vs. weekend day physical activity levels in 97 subjects and found a mean difference of 0.0008 (95% CI = -0.06, +0.06).

### 2.8.6 Summary of Studies using Heart Rate Monitoring

An objective measure of PA at the population level must demonstrate a high correlation with the gold standard techniques, have low associated costs in terms of data collection and analysis, and must not impose a high participant burden. HRM is an accurate technique for assessing free-living PAs in adults, and has been validated against DLW and calorimetry with a correlation of 0.94.[62,63]

Quantifying PA in inactive or sedentary individuals, as well as the elderly, remains challenging. Factors such as individual variation, the amount of time spent in the lower end of the HR spectrum, and the generally lower muscle mass and physical capacities of the elderly[149] contribute to the error associated with PA assessments in these populations. Daily variation within and between individuals can be minimised by generating individual calibration curves which determine the individual's HR vs. $VO_2$ relationship. Although time consuming, this procedure increases the accuracy of EE estimates by providing associated EE and intensity levels of each PA performed during HRM. Still, individual HR can be highly unpredictable for a variety of reasons, and low correlations exist between individual and group calibration curves, even when multiple calibration activities are performed.

The factors mentioned above are generally beyond the researcher's control, although characteristics related to the study design can increase the study's power. The sample population should be large enough to detect significant correlations, and include both genders, a wide range of ages and PA levels, and different ethnic groups when possible. The HRM period can also be used to increase EE estimates. The longer the HRM period, the more accurate the HR data will be. A 5-6 day HRM period is recommended, although participant comfort tends to decrease around the 4-day mark and could influence PA behaviour. Consequently, HRM is an accurate assessment technique feasible for population studies, as the associated expense and participant burden is manageable.

**Table 8.** Energy Expenditure Estimates: Heart Rate Monitoring vs. Gold Standard Methods

| Reference | Main purpose of study | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period/ Calibration Activities | Reference Method and period | Results | Other Statistics | Additional Findings/Comments |
|---|---|---|---|---|---|---|---|
| Kalkwarf *et al.*[130] | Determine accuracy of $HRM_{EE}$ in free-living individuals | N=12F<br>19-27 yrs<br>Healthy college students and staff | 4 days<br><br>Rest, treadmill walking & running sitting, standing, stair climbing, slow/fast milling | Indirect Calorimetry | $HRM_{EE}$ vs. $CAL_{EE}$: group estimates ranged from +2 to +9%<br><br>Individual EE estimates ranged from -53% to +67%. | | Accuracy influenced by type of regression equation used to calculate $HRM_{EE}$ |
| Li *et al.*[68] | Evaluate $HRM_{EE}$ estimates and individual variation | N=40F<br>20-45 yrs<br>Cotton mill workers in Beijing | 16 hours<br><br>16 different 'daily life' activities | Indirect Calorimetry | Inter-individual variation:<br>14.1% to 17.6%<br><br>Intra-individual variation:<br>10.6% to 20.4%, | EE vs. HRM: $R^2$=0.91 ± 0.06 (mean ± SD), p<0.001<br><br>Repeated $HRM_{EE}$ measures:<br>mean diff = -124 ± 1431 kJ/16hr | $HRM_{EE}$ better for groups than individuals |
| Davidson *et al.*[129] | Compare free-living $HRM_{EE}$ and $DLW_{EE}$ estimates | N=9M<br>25-54 yrs<br>Healthy non-smokers with sedentary occupations | 9 days<br><br>Variety of sedentary and exercise activities | DLW and Indirect Calorimetry | Filtering data improved $HRM_{EE}$ estimates from +16.3% (SEM 4.9) to +6% (SEM 4.2) over $DLW_{EE}$ | | HRM can have up to 20% error for individual EE estimates. |

EE = energy expenditure, HRM = Heart Rate Monitoring, DLW = Doubly-labeled Water, CAL = Calorimetry

| Reference | Main purpose of study | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period/ Calibration Activities | Reference Method | Results | Other Statistics | Additional Findings/Comments |
|---|---|---|---|---|---|---|---|
| Rutgers *et al.*[149] | To test the suitability of HRM for 24-hr EE estimates in elderly women | N=13F<br>68-78 yrs<br>healthy, mostly active | 3 days, excluding weekends<br><br>5 activities ranging from sitting to walking 3km/hr | Indirect Calorimetry | Individual calibration curves:<br>r=0.89<br>95% CI = (0.69-0.99)<br><br>Group calibration curves:<br>r=0.93, p<0.02 | | No significant correlation between EE estimated from group and individual calibration curves. |
| Morio *et al.*[131] | Calibrate and validate $HRM_{EE}$ against indirect calorimetry and DLW, respectively, to determine daily EE in free-living elderly | N=12<br>6M, 6F<br>mean = 70.1 yrs<br>SD 2.7<br>sedentary to active | 4 days<br><br>Light to moderate activities | Indirect Calorimetry<br>84 hours (calibration)<br><br>DLW<br>17 days (validation) | $HRM_{EE}$ vs. $CAL_{EE}$:<br>mean difference = -0.1%, SD=5.8%<br><br>$HRM_{EE}$ vs. $DLW_{EE}$<br>mean difference:<br>Males = +4.5%, SD=14.4%<br>Females = +5.9%, SD=8.8% | Intra-individual variation in $HRM_{EE}$:<br>in males = 11.6%, SD=7.6%<br>In females = 7.6%, SD=4.2%<br><br>Intra-individual variation:<br>$CAL_{EE}$ = 7.6%.<br>Walking = 6.3% | $HRM_{EE}$ estimates are more suitable for groups than individuals<br><br>HRM can be used in sedentary to very active subjects with accurate HR-EE calibration |
| Kashiwazaki[133] | Compare 3 calibration procedures for estimating $HRM_{EE}$ to $DLW_{EE}$ | N=10<br>5M, 5F<br>18-65 yrs<br>Bolivian Aymara<br>Healthy | 2 x 24 hours<br><br>Rest, step test | DLW<br><br>2 weeks | $HRM_{EE}$ assessed by Linear regression, log-linear regression, and 2 linear regressions (HRFlex) did not differ statistically from $DLW_{EE}$ | SD of $HRM_{EE}$ estimates:<br>2-3 times greater than $DLW_{EE}$.<br><br>Log-linear EE was best matched to $DLW_{EE}$ | Assessing EE from HRM is best performed at the group level. |

EE = energy expenditure, HRM = Heart Rate Monitoring, DLW = Doubly-labeled Water, CAL = Calorimetry

| Reference | Main purpose of study | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period/ Calibration Activities | Reference Method | Results | Other Statistics | Additional Findings/Comments |
|---|---|---|---|---|---|---|---|
| Strath *et al.*[27] | Examine the validity of adjusting for age and fitness to estimate $HRM_{EE}$, and evaluate HR vs. $VO_2$ relationship during moderate-intensity activities | N=61<br>31M, 30F<br>18-74 yrs<br>Multiethnic (Asian, Hispanic, African American, Caucasian) | During calibration activities<br><br>1-7 various indoor and outdoor activities performed at moderate-intensity | Indirect Calorimetry | $HRM_{EE}$ vs. $CAL_{EE}$:<br>r=0.87<br>SEE = 0.76 METS<br>Mean error = 0.04 METs<br><br>HR accounted for 78% of the variability in EE (SEE=0.76 METS) | HR vs. $VO_2$:<br>r=0.68<br>SEE = 18.23 ml/kg/min<br><br>HR accounted for 47% of the variability in $O_2$ uptake (SEE=18.23 ml/kg/min) | Adjusting for age and fitness levels provides more accurate quantification of free-living PA<br><br>95% CI of error score = (-1.48, 1.56) less than that of accelerometers which range from (-2.3. 2.3) to (-2.7, 3.8) METs |
| Hiilloskorpi *et al.*[69] | Develop gender-specific prediction equations for free-living EE using HR, %HRR, and $HR_{net}$ | N=89<br>42M (19-51yrs)<br>47F (21-53 yrs), healthy volunteers | During calibration activities<br><br>Rest/light activity (<3METs), to max. walking test on treadmill (10METS) | Indirect Calorimetry | Prediction equations using %HRR or $HR_{net}$ generate more accurate EE estimates.<br><br>SEE using:<br>HR = 5.89kJ/min or 1.41kcal/min<br><br>%HRR = 4.22kJ/min or 1.01kcal/min<br><br>$HR_{net}$= 4.51kJ/min or 1.08kcal/min | | Sex and body weight are valuable factors in EE prediction equations. |

EE = energy expenditure, HRM = Heart Rate Monitoring, DLW = Doubly-labeled Water, CAL = Calorimetry

**Table 9.** Energy Expenditure Estimates: Heart Rate Flex vs. Gold Standard Methods

| Reference | Main purpose of study | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period/ Calibration Activities | Reference Method | Results | Other Statistics | Additional Findings/Comments |
|---|---|---|---|---|---|---|---|
| Spurr *et al.*[126] | Compare $HRM_{EE}$ to $CAL_{EE}$ | N=22<br>16M, 6F<br>18-66 yrs | 22 hours<br><br>Rest, 4 cycle ergometer protocols | Indirect calorimetry, 22 hours | $HRM_{EE}$ vs. $CAL_{EE}$:<br>Mean = +2.7<br>SEM = 2.0<br>Error range = -15% to +20%<br>Ave error = 2.7±9.2% | No significant differences observed for TEE or AEE measured by HRFlex and indirect calorimetry | HRM provides accurate TEE and AEE estimates, even in groups as small as (n=4-6) |
| Ceesay *et al.*[63] | Compare $HRM_{EE}$ to $CAL_{EE}$ | N=20<br>11M, 9F | 24 hours<br><br>Rest, cycle ergometer, rowing, stepping, jogging | Indirect calorimetry | Mean = -1.2<br>SEM = 1.4<br>Error range = -11% to +11%<br>Ave error = -1.2±6.2% | Individual calibration:<br>0.94, SD=0.04<br><br>Mean HRFlex (bpm):<br>Males = 86, SD=10<br>Females = 96, SD=6 | Very good predictive power for group estimates of TEE |
| Livingstone *et al.*[62] | Compare $HRFlex_{EE}$ to $DLW_{EE}$ | N=14<br>9M, 5F<br>17-46 yrs | 2-4 days<br><br>Rest, stepping, cycle ergometer | DLW<br>15 days | $HRM_{EE}$ vs. $DLW_{EE}$:<br>Mean = +2.0±17.9%<br>SEM = 4.8<br>Error range = -22% to +52%<br>Males = +5.3±20.6%<br>Females = -4.0±11.5% | $HRM_{EE}$ vs $DLW_{EE}$:<br>Values lay within ±10% of each other.<br><br>95% CI = (-5.0, +5.19) MJ/day | nonsignificant variation in male vs. female HRFlex thresholds |
| Heini *et al.*[144] | Assess and compare total free-living $HRFlex_{EE}$ to $DLW_{EE}$ in a rural farming population | N=8M<br>25 ± 4 yrs<br>Healthy, non-obese volunteers | 2-3 days<br><br>Sedentary activity and various intensities of TM walking | DLW<br>10-12 days<br><br>Direct calorimetry 2x for 15 hours | $HRM_{EE}$ vs. $DLW_{EE}$:<br>mean difference = 314 ± 785 kcal/day (nonsignificant)<br>Error range = +5.2% to +17.4% | Both methods yielded similar PA levels:<br>2.4 x BMR | Authors suggest high range of $HRM_{EE}$ values due to high variability in daily HR |

(T)EE = (total) energy expenditure, HR = Heart Rate, HRM = Heart Rate Monitoring, DLW = Doubly-labeled Water, CAL = Calorimetry, BMR = Basal Metabolic Rate, PAL = Physical Activity Level

| Reference | Main purpose of study | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period/ Calibration Activities | Reference Method | Results | Other Statistics | Additional Findings/Comments |
|---|---|---|---|---|---|---|---|
| Wareham *et al.*[60] | Assess the feasibility of $HRM_{EE}$ for epidemiological studies, and describe TEE and PA pattern | N=164<br>74M, 90F<br>30-40 yrs<br><br>Weekday vs. weekend day comparison:<br>N=97 | 4 days<br><br>Rest, cycle ergometer test | Indirect calorimetry | EE pattern vs. PAL:<br>Males r=0.77,<br>Females r=0.71<br><br>Est.$VO_2$ vs. PAL:<br>Males r=0.50,<br>Females r=0.42,<br>p<0.01 | Weekday vs. Weekend day:<br>No differences observed.<br>Mean paired difference = 0.0008,<br>95% CI =<br>(-0.06, +0.06) | HRM is a feasible method for assessing the pattern and total level of EE in mid-sized epidemiological studies. |
| Davidson *et al.*[129] | Compare free living EE estimated by HR and DLW | N=9M<br>25-54 yrs<br>Healthy, non-smokers with sedentary occupations | 9 days HRM, DLW and activity diary<br><br>Variety of sedentary and exercise activities | DLW and indirect calorimetry | Filtered $HRFlex_{EE}$ data overestimated EE by +9.3% compared to $DLW_{EE}$<br>SEM = 4.2 | | HRM can have up to 20% error for individual EE estimates. |
| Rennie *et al.*[61] | Assess feasibility of HRM without individual calibration | N=97<br>40-70yrs<br>volunteers | 4 days<br><br>Rest, incremental exercise on cycle ergometer | Indirect calorimetry | $HRFlex_{EE}$ vs. $CAL_{EE}$<br>r = 0.93<br>(p<0.001)<br><br>PAL r = 0.82,<br>95%CI =(0.74, 0.87)<br>p<0.001<br>Males r=0.83<br>Females r=0.84<br>p<0.01 | Resting EE<br>r=0.73,<br>p<0.001 | This non-exercise regression approach may allow HRM to be applied to larger epidemiological studies |

(T)EE = (total) energy expenditure, HR = Heart Rate, HRM = Heart Rate Monitoring, DLW = Doubly-labeled Water, CAL = Calorimetry, BMR = Basal Metabolic Rate, PAL = Physical Activity Level

| Reference | Main purpose of study | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period/ Calibration Activities | Reference Method | Results | Other Statistics | Additional Findings/Comments |
|---|---|---|---|---|---|---|---|
| Ekelund *et al.*[70] | Compare $HRFlex_{EE}$ to $DLW_{EE}$ in young athletes, using 2 HRFlex definitions | N=8M<br>Mean age = 18.2 ± 1.3 yrs<br>Speed skater athletes | 2 x 8 days<br><br>2 different training regimens | DLW, 2 x 10 days | HRFlex1 produced significantly lower HR values compared to HRFlex2 (p=0.004)<br><br>No significant period (p=0.83) or method (p=0.44) effect was observed on TEE measured by 3 methods | Individual EE differences compared to DLW:<br><br>$HRFlex1_{EE}$ -8.8% to +24.2%<br><br>$HRFlex2_{EE}$ -10.6% to +21.0% | Walking, running and cycling activities performed for calibration purposes appeared to represent free-living activities on a group level |

(T)EE = (total) energy expenditure, HR = Heart Rate, HRM = Heart Rate Monitoring, DLW = Doubly-labeled Water, CAL = Calorimetry, BMR = Basal Metabolic Rate, PAL = Physical Activity Level

### 2.8.7 Concepts of Physical Activity Questionnaire Validation

Self-report PAQs remain the most feasible instruments for epidemiological and surveillance studies aiming to quantify PA levels.[3,8,32,33,36-43] The wide distribution, low cost and low respondent burden associated with administering PAQs make them advantageous to other self-report and objective measurement tools.[41,42] Many PAQs exist and the appropriate instrument depends on the research goals. However, the validity of the chosen instrument must first be established to ensure it accurately assesses the true exposure of interest prior to being utilised for scientific research. Compared to reliability estimates, the validity of a PAQ is not frequently reported, and reported values are typically low, possibly due to using published EE costs of PAs that do not account for inter-individual differences. In addition to PAQ length and detail, the logical development and construction of a PAQ can influence performance against a validation technique. These details should therefore be described alongside validation to inform readers what particular PA dimensions and contexts the PAQ aims to assess.[44]

A formal meta-analysis of PAQ validation studies is difficult due to differences in validation methods and analyses.[47] In an effort to clarify issues around appropriate validation instruments and unify validation studies to similar standards, Rennie et al.[36] compiled a checklist of 6 criteria for researchers to address. The important aspects identified include:

1) Has the dimension of PA that the instrument is purported to measure been clearly defined?
2) Does the validation method chosen measure the true exposure of interest and has it been applied in the same time frame of reference?
3) Has correlated error between the validation method and the PA instrument been avoided as far as possible?
4) Is there a close relationship between the validation method and the appropriate 'gold standard' instrument?
5) Is the sample chosen representative of the population to whom the PA instrument will be administered?
6) Have appropriate statistical techniques been employed to assess the validity of the PA instrument?

Validation Techniques for Physical Activity Questionnaires

Ideally, PAQs should be validated in terms of their criterion validity (comparison to an objective, more precise assessment of PA).[29] However, the lack of an accepted reference criterion measure has led to an emphasis on construct validity (validation against other variables related to PA).[29,50] Multiple validation methods have been utilised, including fitness components such as $VO_{2max}$ and physical work capacity (PWC), obesity, pulmonary function, caloric intake, PA diaries, motion sensors, HRM, DLW, and other previously validated PAQs.[22,50] The flaws in many of these validation techniques have contributed to the generally limited validity of PAQs despite over 40 years of extensive use.[29] For example, subjective instruments such as PA diaries or other PAQs introduce recall bias and correlated error, and are inadequate for establishing PAQ validity.[46] Additionally, utilising markers of obesity, pulmonary function, and fitness components does not reflect a direct measure of PA.[46]

The issue of selection bias is introduced when using fitness components as validation methods, as exclusion criteria limit the sample population to 'apparently healthy' individuals.[147] Although submaximal exercise tests are more inclusive, $VO_{2max}$ and PWC are best correlated to vigorous-intensity activity.[36] Moderate correlations ranging from 0.48 – 0.55 for 'hard' and 'very hard' activity were reported in fitness validation studies. However, the correlations plummet to 0.02 and 0.13 for light and moderate activity, respectively. Furthermore, fitness variables are inappropriate validation methods because they do not provide a direct assessment of individual TEE or PA patterns. For example, a fit individual may not necessarily show high TEE, just as an individual with high TEE may represent high participation in moderate-intensity activity rather than a high fitness level.[36] Furthermore, fitness levels have a genetic component and are affected by factors other than habitual PA.

Validity coefficients typically show only fair to poor agreement (0.2 – 0.4),[47] although researchers have reported coefficient values between 0.3-0.5 as "reasonably valid".[29] However, an ideal validation instrument should demonstrate a correlation of at least 0.6 with the underlying true exposure.[36] Validation studies using DLW, the gold standard method, have found correlations ranging from 0.57-0.79 with PAQs.[29] HRM and accelerometers have been accepted as PAQ validation instruments due to their objectivity and lack of correlated error.[36] A review of 6 validation studies conducted on adults wearing accelerometers revealed validity coefficients ranging from 0.21-0.53 for total PA levels.[42] That said, HRM has several advantages over motion sensors in terms of accuracy, reliability, risk of mechanical failure, the range of PAs captured, and higher correlations with PAQs.[36] Furthermore, HRM has been validated against DLW and calorimetry with very high correlations.[62,63]

## Sample Size and Selection

Any conclusions related to the validity of a PAQ are limited to the specific population in which the study was conducted and its use is restricted to the originally intended purpose for which it was designed.[45,46] PAQs are typically designed for administration at the population level, which includes individuals of both sexes, representing different demographic, ethnic or cultural groups over a wide range of PA levels. Careful consideration is essential when determining sample size and selection procedures to ensure the target population for which the PAQ was designed for is adequately represented.[46,90]

An ideal validation study sample should be large enough to detect significant findings.[90] Typically, small sample sizes have a direct impact on precision of the results, leading to nonsignificant correlations or large confidence intervals, thereby limiting the applicability of the findings.[146] In a well-designed experiment the power to detect the desired effect will be set to 80% ($\beta$=0.2), 90% ($\beta$=0.1), or even 95% ($\beta$=0.05).[90] Nutritional epidemiology has produced calculations to determine the sample size required for detecting associations at a particular level of power and significance (see below), and the issues in PA are analogous.[113]

$$n = 2\sigma^2(Z_{\alpha/2} + Z_\beta)^2 / d^{*2}$$

Where $\sigma$ = Standard deviation

$d^*$ = difference between groups

$\alpha$ = fixed significance level

$\beta$ = power

The representativeness of the sample is also important, so that results can be generalised to a higher degree when the sample population closely represents the target population.[145] The ideal recruitment process would include random selection and limited exclusion criteria, although validation studies are often carried out on small subgroups of volunteers due to the participant burden associated with the gold standard procedure.[36]

Absolute vs. Relative Validity

Validation studies typically address the validity of a self-report instrument in relative terms, and results are typically presented by reporting correlations with a criterion measure that objectively and accurately measures PA. Such information is important for making associations with health outcomes or assessing outcomes in controlled intervention studies. However, for epidemiological studies, Sallis & Saelens[42] proposed that absolute validity data become a major focus of validation efforts. Measuring absolute levels of PA enables researchers to determine the proportion of the population who meet current PA recommendations, and is also important for defining dose-response relationships between PA and health outcomes.

### 2.8.8 Validation of Physical Activity Questionnaires using Heart Rate Monitoring

Although many studies have used HRM to assess PA levels and patterns in adults, an extensive search revealed very limited use of HRM as a PAQ validation method in adult samples. The following section is a comprehensive review of three PAQ validation studies which have used or included HRM as one of the validation techniques, and one study which also validated a PA index. The studies were conducted between 1984 and 2003, and included sample sizes ranging from 30 to 173 participants. Although repeatability issues are addressed, details pertaining to secondary validation instruments used simultaneously in the following studies were omitted, as they are not directly related to the topic of this thesis.

**Taylor et al.[140]** – This study evaluated the validity of the Stanford 7-day recall PAQ which was administered in an epidemiological study (N=497) conducted at Stanford University. The PAQ was designed to assess hours of sleep, type and total duration of 'light', 'moderate', 'hard', and 'very hard' activities. The total sample consisted of 30 Caucasian male volunteers aged 34-69 yrs. Half the sample underwent maximal treadmill tests to establish individual HR vs. EE relationships, and HRM was recorded by a Vitalog® activity monitor worn during days 1-3. This device differs from more modern HR monitors in that HR is assessed by three chest electrodes rather than a transmitter belt, and a motion sensor attached at the front thigh confirms elevated HR readings are due to PA rather than emotional stimuli. All subjects completed PA Logs for days 1-7, which recorded sleep time, type, duration and perceived intensity of PAs (examples of activities at each intensity were provided). The PAQ was administered after day 7, and data were converted to daily MET-hours by multiplying by 1, 1.5, 4, 6, and 10, depending on the activity, while light-intensity activity was calculated as the difference of total hours of sleep and all reported activities from 24 hours. Usable Vitalog® data was available from 12 participants. HR values corresponding to 4-5 METs, 6-9 METs, and ≥ 10 METs were categorised as ‘moderate’, ‘hard’ and ‘very hard’ activity, respectively. Data were then translated into TEE (kcal/day or kcal/kg/day) and total duration for each activity level.

A secondary aim of this study was to investigate any bias that may exist when recalling PA (conditioning, leisure, household, occupational). The frequency of activities was in 94% agreement between the Vitalog® and PA Log data. In terms of intensity and type of activity, conditioning (74%) and leisure activities (100% - golf, soccer, racquet, ‘others’) were recalled with greater accuracy, respectively.

Although values for mean 24-hr TEE (kcals/day) assessed by Vitalog® (3021 ± 707) and PAQ (2964 ± 573) were reported, the degree of correlation was not included. In regard to activity duration, Vitalog® vs. PAQ comparisons in separate activity levels were not reported, although it was reported that no significant differences in mean duration of ‘moderate and above’ activity were found between the three methods of measurement. Direct comparisons exist for Vitalog® vs. PA Log data and PA Log vs. PAQ, allowing only indirect Vitalog® vs. PAQ comparisons. Although Vitalog® vs. PA Log comparisons revealed an over-reporting of duration in ‘hard’ and ‘very hard’ activities, total duration in ‘very hard’ activity was significantly correlated in Vitalog® vs. PA Log ($r=0.91$, $p<0.001$) and PA Log vs. PAQ ($r=0.55$, $p<0.01$) comparisons. While the researchers found the PA Log to be more accurate than the PAQ, they concluded that more accurate, less expensive and unobtrusive assessment of PA could be accomplished by either method when combined with 3-4 days of HRM.

**Sobngwi et al.[67]** – The authors of this study aimed to assess the validity and reliability of the Sub-Saharan Africa Activity Questionnaire (SSAAQ), which addresses occupational, transport (walking and cycling), and leisure time PA contexts over ‘the past year’. The PAQ was revised to include culturally specific examples of physical activities performed in this population, which were provided by 20 volunteers during pilot testing. The study sample (N=89) consisted of 44 male and 45 female Cameroonians living in urban (n=35) and rural (n=54) areas, aged 19-68 yrs. The SSAAQ was administered twice to each participant during interviews conducted 10-15 days apart. Between the interviews, each subject was objectively monitored for 24 hours via an accelerometer (rural population only), a HRM, or both.

Reliability was assessed from PAQ responses provided at each interview. In general, the SSAAQ was highly reproducible for TEE and most PA contexts, although LTPA showed the lowest reproducibility coefficients with test-retest differences in excess of 2 hours.

The SSAAQ completion times ranged from 5-26 minutes, and PAQ validity was assessed with Spearman correlations between PAQ data and objective measures from HR monitors (without individual calibration) and accelerometers. However, accelerometers were worn by rural participants only and revealed generally weaker, less significant correlations with the SSAAQ. HRM data showed significant correlations to the different PA contexts (occupation: $r=0.44$-$0.72$, $p<0.05$; walking: $r=0.50$-$0.62$, $p<0.05$; LTPA: $r=0.38$, $p<0.05$; and TEE: $r=0.41$-$0.63$, $p<0.05$). Urban women showed consistently high correlations for each activity context, ranging from 0.56 (walking) to 0.72 (occupational activity). Although statistically significant, the lowest correlation values were seen in rural women, ranging from 0.38 (LTPA) to 0.54 (walking). Compared to urban participants, the rural subgroup had a higher proportion of individuals with intense occupational activities ($p<0.05$), and walked more often at a brisk pace ($p<0.05$). The authors concluded that the SSAAQ is a valid instrument with acceptable repeatability and completion time.

**Wareham et al.[44]** - This study assessed the validity and repeatability of the modified European Physical Activity Questionnaire (EPAQ2), a comprehensive instrument designed to measure the different sub-dimensions of PA over the past year. EPAQ2 uses closed questions to capture EE and fitness enhancing elements of PA performed at home ($EE_{home}$), at work ($EE_{work}$), or for recreation ($EE_{rec}$), as these components are related to endpoints such as aerobic intensity, overall EE and load bearing. CRF (submaximal) and HRM-derived EE served as the validation methods carried out on 173 participants aged 40-65 yrs, a subgroup from a population-based cohort study in Ely, Cambridgeshire. Individual calibration was performed on a cycle ergometer, and the HRFlex method was used to analyse 4 consecutive days of HRM. These measures were repeated on 4 separate occasions over one year, with the EPAQ2 administered at the final visit.

HRM data were summed to estimate daytime EE, as well as the proportion of time when the PA ratio (minute EE:minute BMR) was ≥5. This cut point discriminates light-intensity activity from moderate- and vigorous-intensity activities. Objective data indicate males had significantly higher levels of CRF and daytime EE, and time spent in activity with an elevated PA ratio ($p<0.001$), compared to females. EPAQ2 results indicated that, compared to males, females reported significantly higher totals for

$EE_{home}$ ($p<0.001$) and significantly lower values for $EE_{work}$ ($p=0.013$) and $EE_{rec}$ ($p=0.009$), although no significant difference was observed for time spent in vigorous recreational activity. Validity of EPAQ2 components revealed modest correlations for $EE_{rec}$ (0.13) and $EE_{work}$ (0.17, $p<0.05$) compared to HRM. Similar correlations were observed when $EE_{rec}$ (0.16, $p<0.05$) and vigorous activity (0.16) were validated against CRF.

Repeatability was assessed on 399 randomly selected participants, who completed the EPAQ2 three months after the last interview. No statistical differences were found between the original cohort sample and the repeatability subsample. Repeatability coefficients for men and women were ≥ 0.68 and > 0.60, respectively.

**Wareham et al.[45]** - This study addresses the validity and repeatability of a simple PA index used in the European Prospective Investigation into Cancer and Nutrition (EPIC) study, described in the previous review. The main cohort study had a sample size of 30,410 participants aged 40-65 yrs. The PA index was derived from the EPIC PAQ and served to categorise participants into four categories of overall activity based on time spent in occupational and recreational (cycling and other exercise) PA contexts. This particular combination was chosen, as the inclusion of domestic activity elicited a lower correlation with daytime EE. The four levels of PA index are presented in Table 10, along with the associated percentage of participants in each category.

The validity of the PA Index was assessed on 173 randomly selected subjects, and showed significant positive correlations with mean daytime EE with ($r=0.28$, $p<0.001$) and without ($r=0.44$, $p<0.01$) adjusting for age and/or sex. Significant positive correlations were also seen between mean day PAR and $VO_{2max}$ for each level of the PA Index. In sex-specific analyses adjusted for age, the correlation in men was 0.30 ($p<0.01$) and 0.23 in women ($p<0.05$), although the significance of the HRM vs. PA Index correlations diminished when the sample was stratified by sex. The PA Index demonstrated high repeatability with a weighted kappa of $\kappa=0.6$ ($p<0.0001$). The authors concluded that this 4-level PA Index is a simple tool with face validity that can be used on a global scale to rank participants by PA levels in population surveillance studies. The use of this index as a screening instrument in healthcare settings was also suggested.

**Table 10.** Physical Activity Categories of EPIC participants (N=30,410)[45]

| PA Category | % | Description |
|---|---|---|
| **Inactive** | 30.7 | Sedentary job and no recreational activity |
| **Moderately Inactive** | 28.7 | Sedentary job with < 0.5 hours/day recreational activity<br>*Or* Standing job with no recreational activity |
| **Moderately Active** | 22.1 | Sedentary job with 0.5-1.0 hours/day recreational activity<br>*Or* Standing job with 0.5 hours/day recreational activity<br>*Or* Physical job with no recreational activity |
| **Active** | 18.5 | Sedentary job with > 1 hours/day recreational activity<br>*Or* Standing job with > 0.5 hours/day recreational activity<br>*Or* Physical job with at least some recreational activity<br>*Or* Heavy manual job |

Summary of Physical Activity Questionnaire Validation Studies

The reviewed validation studies are presented in Table 11. Using the checklist criteria compiled by Rennie et al.,[36] it is apparent that some vital aspects have not been met by the reviewed validation studies. The specific dimensions, contexts, and time frame of PA that each instrument aimed to measure were clearly defined in all three studies. Additionally, correlated error is minimised, as HRM has been validated against the gold standard techniques with a correlation of 0.94.[62,63] However, issues surrounding sample populations, the time frame of reference, and statistical procedures are important matters which affect the studies' strength and interpretation of results.

The 7-day Stanford Recall PAQ was designed to be used in community-based health-education risk-reduction studies and was administered in a large epidemiological study. However, the results are not applicable to opposite or both sex populations due to the limited demographics of the sample population (30 white males aged 34-69 yrs).[36,46] Direct comparisons between HR data and PAQ responses were not reported by Taylor et al.,[140] so inferences could only be made from the HR vs. PA Log and PA Log vs. PAQ comparisons. Although no significant differences were reported between the three instruments, it could be argued that completion of daily PA Logs (days 1-7) may have influenced participant recall on the PAQ (day 7). The HRM was worn on days 1-3 and direct comparison with PAQ results from these days would have provided more objective validation data.

The SSAAQ validated by Sobngwi et al.[67] measures LTPA and occupational PA contexts in the past year. However, a HRM period of 24 hours does not seem appropriate for analysing HR variability and the time frame of the PAQ. The individual calibration procedure typical of HRM studies was not performed due to “practical reasons”. Instead, the researchers examined individual HR variability as a reflection of activity status. A 24-hour HRM period does not account for daily HR variability or the influence of seasonal variation on habitual PA levels and patterns. However, this study provides a unique opportunity to compare urban and rural sample populations, and the use of culturally-specific examples of activities would have improved PAQ responses, as the SSAAQ was developed for this particular population.

The study by Wareham et al.[44] was the largest PAQ validation study with a sample of 173 subjects aged 40-65 yrs. The EPAQ2 assessed ‘past year’ activity, and validation measures were repeated through the same time frame, allowing for seasonal variation over the course of one year. However, the highest validation coefficients range from 0.13 – 0.17, which the researchers reported as ‘modest’, but validation instruments should demonstrate correlations of at least 0.6 with the underlying true exposure.[36] The PA Index was significantly correlated with HRM ($r=0.44$, $p<0.01$), although the recreational activities were restricted to higher-intensity activities because such activities are recalled with greater accuracy in PAQs. Providing a wider range of activities for participants to report on would most likely produce a much lower validity coefficient.

**Table 11.** Validation Studies of Physical Activity Questionnaires using Heart Rate Monitoring

| Reference | PAQ Characteristics (time frame, PA dimensions and contexts) | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period | Results | Additional Findings/Comments |
|---|---|---|---|---|---|
| Taylor *et al.*[140] | 7-day Stanford Recall PAQ<br><br>time spent sleeping, type, duration and intensity of activities over the 'last 7 days' | N=30M<br>34-69 yrs<br>Caucasian<br><br>HRM data:<br>N=12 | HRM:<br>3 days<br><br>Diary:<br>7 days | PAQ vs. PA Logs:<br>r=0.81, p<0.01<br><br>This instrument is particularly useful for assessing kcal/day, duration and intensity of conditioning activities. | Frequency of moderate or greater levels of activity is accurately reported.<br><br>Conditioning activities (74%) are the best recalled, followed by home (68.5%) or leisure (62.5%) and job activities (61.5%). |
| Sobngwi *et al.*[67] | Sub-Saharan Africa Activity Questionnaire (SSAAQ)<br><br>Occupational, transport (walking and cycling), and LTPA contexts over 'the past year' | N=49<br>45F, 41 yrs<br>4M, 43 yrs | 24 hours | HRM vs. PA Contexts:<br><br>Occupational: r = 0.44-0.72<br>Walking: r = 0.50-0.62<br>LTPA: r = 0.38<br>TEE: r = 0.41-0.63<br>p<0.05 | SSAAQ is a valid instrument with acceptable repeatability and completion time. |
| Wareham *et al.*[44] | modified European Physical Activity Questionnaire (EPAQ2)<br><br>Home, work, and recreational activity performed over 'the past year' | N=173<br>40-65 yrs | 4 x 4 days | HRM vs. EE:<br><br>$EE_{rec}$ (r=0.13)<br>$EE_{work}$ (r=0.17, p<0.05) | High repeatability of PA indices:<br><br>Males: ≥ 0.68 for all indices except work<br><br>Females: > 0.60 for all indices except work and vigorous sports |

(T)EE = (total) energy expenditure, HRM = Heart Rate Monitoring, PA = Physical Activity, LTPA = Leisure-time Physical Activity

| Reference | PAQ Characteristics (time frame, PA dimensions and contexts) | Sample Characteristics (N, Age, Sex, Ethnic, other) | HRM Period | Results | Additional Findings/Comments |
|---|---|---|---|---|---|
| Wareham *et al.*[45] | European Prospective Investigation into Cancer and Nutrition (EPIC) Study PA Index<br><br>Self-reported time spent in occupational and recreational (cycling and other exercise) PA contexts was used to classify participants into 1 of 4 PA groups:<br><br>Inactive<br>Moderately Inactive<br>Moderately Active<br>Active | N=173<br>40-65 yrs | 4 x 4 days | PA Index vs. HRM:<br>$r=0.44$, $p<0.01$<br><br>Adjusted for age and sex:<br>$r=0.28$, $p<0.001$<br><br>High repeatability:<br>weighted $\kappa=0.6$, $p<0.0001$ | The 4-level PA Index is a simple tool with face validity that can be used on a global scale to rank participants by PA levels in large epidemiological studies.<br><br>This index could also be utilised as a screening instrument in healthcare settings. |

(T)EE = (total) energy expenditure, HRM = Heart Rate Monitoring, PA = Physical Activity, LTPA = Leisure-time Physical Activity

## 2.9 INTERNATIONAL SURVEILLANCE OF PHYSICAL ACTIVITY

Encouraging populations to adopt and maintain physically active lifestyles that meet or exceed current recommendations is an objective of global importance.[8,13,15,47] Self-report instruments are the only feasible methods for PA assessment in population studies.[8] Although precise measures of EE are not possible with subjective tools such as PAQs, the data are beneficial for relative comparisons that rank individuals, groups, populations and countries across the activity spectrum.[49] The term 'surveillance' refers to systematic ongoing collection, collation, analysis, interpretation, and dissemination of consolidated and processed data to those who need to know, and is necessary for the planning, implementation, and evaluation of public health practice.[150] PA population surveys are typically used to determine the prevalence, trends, and socio-demographic distribution in PA participation. Prevalence and trends in PA data can provide an interesting global view of PA from intra- and inter-country comparisons, while socio-demographic distribution data provide cross-cultural comparisons, which help identify determinants of PA and determine if health promotion resources are being allocated properly.[8]

However, PA surveillance requires standardisation and consistency prior to making direct comparisons of research findings within and between countries. Direct comparisons of PAQ validity within or between groups are difficult, as the relevance of study results are specific to the sample population's characteristics (i.e. social, cultural, age, gender, activity level) and the population for which the instrument was designed.[8,46] The need for culturally-specific terminology and examples pertaining to PA dimensions and contexts is critical for ensuring respondents' comprehension and accuracy of self-report,[8,49] and allowing for greater extrapolation of validity results.[146] There is a need for a simple PAQ which, in addition to obtaining valid and reliable PA data, allows for direct comparisons of results regardless of the population in which it was administered.[8] An internationally agreed upon instrument would contribute to all aspects of PA research, including population surveys, studies of the health consequences of physical inactivity, studies of the determinants of PA participant, and intervention evaluation.[8]

### 2.9.1 The International Physical Activity Questionnaire

Until recently, an internationally accepted PAQ was nonexistent. In the late 1990's, eight versions of the international physical activity questionnaire (IPAQ) were developed which varied in length (4 short, 4 long) and reference period ('last 7 days' or a 'usual week'), and were designed to be either self- or telephone-administered to adults aged 18-65 years. The frequency, intensity and duration of PA, as well as sedentary behaviour, are assessed in these instruments. In 2000, reliability (test-retest) and validity (against accelerometer counts) studies were conducted in 12 developed and developing countries, with standard methods used to translate and adapt the questionnaires to the different countries.[151]

Sample populations of 744 and 781 adults tested the long (pooled ρ=0.33, 95% CI = 0.26 – 0.39) and short forms (pooled ρ=0.30, 95% CI = 0.23–0.36), respectively, against accelerometer counts. The IPAQ versions showed "fair to moderate" validity (~ρ=0.30) and high reliability (ρ=0.80). Respondents generally favoured the short forms over the long forms, which were "too long and repetitive", and were also associated with a wider range of correlation values. Nine of the 14 testing centres reported a preference for the 'last 7 days' over the 'usual week' reference period. The IPAQ-short 'last 7 days' version was recommended for prevalence studies and enabling international comparisons. These studies concluded that the IPAQ can be confidently self- or telephone-administered in developed countries and urban populations in developing countries, and can be adapted to suit different cultures. However, researchers should be cautious with rural or low literacy populations in developing countries.[151]

### 2.9.2 The Global Physical Activity Questionnaires

The WHO Stepwise Approach to Surveillance (STEPS) of non-communicable disease (NCD) risk factors is a global surveillance strategy which was created to provide standard methods and tools for countries to collect population data on NCDs and their risk factors, including physical inactivity.[7,47] The global physical activity questionnaire (GPAQ) is the WHO STEPS instrument, and was redesigned in February 2002 to capture the duration, frequency, and intensity of PAs performed for recreation/sport/leisure, occupation, and transport purposes, as well as sedentary behaviour, in the last 7 days.[47] Smoking habit is also captured.

### 2.9.3 Development of New Zealand Physical Activity Questionnaires

The Physical Activity Joint Monitoring Group (PAJMG) is made up of representatives from New Zealand's Ministry of Health (MOH), the Hillary Commission, and Statistics New Zealand.[6] In an effort to improve national surveillance of PA, the PAJMG created 2 PAQs, a long form (NZPAQ-LF) and a short form (NZPAQ-SF). Both PAQs measure the frequency, intensity and duration of PAs performed in all contexts. However, the NZPAQ-LF also collects information pertaining to the type of PAs performed and distinguishes between duration of moderate- and vigorous-intensity levels. The NZPAQ-LF, which is essentially a 7-day PA diary, also assesses PAs in each context, which allows for assessment of trends and variations in the level and distribution of PA in the NZ population.[28] Measuring additional domains of PA has many benefits, as many people may not perform PA in leisure/sport/recreational context, but instead are physically active for occupation, transportation, household, lawn/garden purposes. On one hand, measuring PA performed in all possible contexts has the potential of increasing measurement error, but also has the potential to decrease measurement error and provide better representation of total PA levels.

The NZPAQ-SF was designed with the IPAQ-short form in mind, but modified to reflect NZ culture and conditions, and to correlate with the NZPAQ-LF. The differences between IPAQ-short and NZPAQ-SF, and the rationale for these changes, are as follows:

- Showcards - The NZPAQ-SF instructs respondents to refer to the showcards, which include examples of moderate- and vigorous-intensity PAs, prior to reporting duration and frequency of PAs at these intensities. The showcards assisted participants with the concepts of moderate- and vigorous-intensity PAs, and enabled them to consider PAs in all contexts.
- Format of question numbering – The IPAQ-short uses a 1a and 1b format to determine days per week (a) and minutes per day (b) of each PA, while the NZPAQ-SF renumbered each question separately, to coincide with numbering from the NZHS. Hence, there are 4 questions on the IPAQ-short (1a, 1b, 2a, 2b, 3a, 3b, 4) and 8 questions on the NZPAQ-SF.
- Topic of Questions - The NZPAQ-SF replaced the 'time spent sitting question' with 'time spent active' and 'stage of behaviour change' questions, which were preferred by the MOH, for whom the NZPAQ-SF was initially designed for.
- Order of questions – The IPAQ-short addresses vigorous- then moderate-intensity PA, followed by brisk walking and time spent sitting. The NZPAQ-SF first addresses brisk walking, then moderate- and vigorous-intensity PA, time spent 'active', and ends with the 'stage of behaviour' question. Pilot testing of this validation study resulted in a recommendation to change the ordering of questions, as respondents displayed a tendency to report most PAs into the vigorous-intensity category when that question was asked first. Changing the order of the questions reduced the misclassification of PA intensity.

The NZPAQ-SF provides an opportunity for NZ-specific measures of PA participation in a shorter version compared to the NZPAQ-LF. However, the drawback of modifying the IPAQ-short, an instrument designed for international comparison of PA levels, is the loss of inter-country comparisons between NZ and other countries utilising the IPAQ-short.

Current PA recommendations advocate 30 minutes of at least moderate-intensity endurance-type PA on most, preferably all, days of the week, and suggest maximum health benefits are attained when PA is spread over at least 5 days of the week.[3,6] Both PAQs are capable of determining if individuals, groups, or populations are meeting current PA recommendations, as they capture the number of days in the last 7 days that a person has been 'active'. Furthermore, recent findings report health benefits associated with total accumulation of PA throughout the day rather than in 30-minute intervals. This concept, referred to as 'snacktivity', provides incentive and encouragement to individuals unaccustomed to regular PA. 'Snacktivity' can be assessed by the NZPAQ-LF because it captures the number of times activity bouts of at least 10 minutes were performed on each of the last 7 days.[6]

New Zealand Physical Activity Categories

- **Physically Inactive:** The NZPAQs classify physically inactive individuals as either 'sedentary' or 'relatively inactive'.[105]
    - Sedentary: No sports or leisure-time PA in the 4 weeks before the interview
    - Relatively Inactive: Less than 2.5 hours of PA in the last 7 days, or some leisure-time PA in the previous 4 weeks (but not necessarily the last 7 days)

- **Physically Active:** New Zealanders who regularly participate in physical activities are categorised as either 'relatively active' or 'highly active', depending on the total duration of activity in the last 7 days.[105]
    - Relatively Active: At least 2.5 hours of PA, but less than 5 hours in the last 7 days
    - Highly Active: 5 or more hours of PA in the last 7 days

Validation of New Zealand Physical Activity Questionnaires

The NZPAQ-SF and NZPAQ-LF, developed by the PAJMG, were developed to be incorporated into the NZHS and NZSPAS. In 2003, a validation study was conducted which compared both NZPAQs against HRM. The IPAQ-long was also administered to determine how well the NZ instruments correlated with the internationally accepted instrument. The IPAQ version administered in this study has been recommended for research purposes,[151] and captures similar information to the NZPAQ-LF. Questions from the NZSPAS, pertaining to sport and recreation PAs taken part in during the last 12 months, 4 weeks, and 2 weeks, stair-climbing, and socioeconomic status, were combined with the NZPAQ-LF instrument, which is referred to as the Main PA Table throughout this thesis (Appendix A, pg.251). The methodology and findings of the NZPAQ validation study are discussed in Chapters 3 and 4, respectively.

## Chapter Summary

Very few studies exist using HRM, an objective measurement technique strongly correlated with DLW and calorimetry, to validate PAQs. In this study, HRM with individual calibration is considered the 'gold standard' method, and was used to validate the NZPAQs for the first time, as well as an international instrument (IPAQ-long), which has only been validated by accelerometry. This thesis also compares PA to CRF, investigates these variables' relationships to CV risk factors, and provides a population-specific compendium of PAs, all which make substantial, original contributions to PA research in NZ.

# CHAPTER 3

# STUDY DESIGN AND METHODS

This chapter describes the overall study design, methodology, and data analyses. Recruitment and selection of this study's sample, protocols for data collection during each visit, and heart rate monitoring (HRM) with individual calibration are explained in detail. Data conversions and processing techniques for determining subjective and objective physical activity (PA) levels are included, in addition to assessment of cardiorespiratory fitness (CRF) levels and calculation of metabolic equivalents (METs) for PAs performed by the New Zealand (NZ) population. This chapter is concluded by stating the hypothesis for this research study.

## 3.1 STUDY DESIGN

Between November 2002 and July 2003, two NZ physical activity questionnaires (NZPAQs) and one international physical activity questionnaire (IPAQ-long) were validated in 186 adults aged 19-86 yrs. PA levels were measured objectively by HRM with individual calibration, which is highly correlated (0.94) to gold standard methods. For the purpose of analyses, and in subsequent chapters of this thesis, HRM was deemed the gold standard method for questionnaire validation.

### 3.1.1 Participant Recruitment

Ethics approval was obtained from the Auckland Ethics Committee. Participants were recruited from community organisations and a general practitioner register to ensure PA patterns were representative of free-living adults. Māori participants were recruited through Hoani Waititi Marae in Henderson and the Atawhai Māori Wardens in Mangere. Pacific participants were recruited through Vai Oe Moui Tongan Methodist Church in Henderson and the Auckland District Health Board. The Pacific sample consisted of 41 Tongan, 16 Samoan, 3 Niuean, 3 Cook Island Māori, 1 Fijian, and 1 Rotuman participant. The 60+ Pacific participants were all of Tongan ethnicity, and the majority of the 18-39 yrs and 40-59 yrs age groups were Samoan. NZ European/Other participants were recruited from a general practice register in Glen Innes. Response rates from GP practice were not recorded, as the staff members were unable to fit this into their existing workload. Because this was a non-random selection process (the researchers aimed to recruit equal numbers of participants in activity levels, age-, gender- and ethnic groups), it was assumed this would not be a representative sample.

Ethnic-specific community information nights were held for Pacific and Māori adults aged 18 years and older. NZ European/Other adults were invited to participate (by phone) by staff from participating general practices. Individuals interested in participating received an information sheet (Appendix A, pg.228), either by post or by attending an information night, and were contacted by phone within two days to confirm participation, screen for exclusion criteria, and make arrangements for Visit 1.

### 3.1.2 Sample Size

Rennie & Wareham[36] suggest that sample size calculations for PA studies were analogous to those produced for nutritional epidemiology. They explain that if the intention is to estimate population level EE using HRM, the number of subjects required can be computed with the standard deviation from previous studies. The result suggested 90 subjects were required to estimate population level EE (± 15%) for validation studies, with a significance of $p=0.05$ at 90% power.[36] The planned sample size was 180 participants, equally distributed between gender (90 male, 90 female), ethnicity (60 European/Other, 60 Māori, 60 Pacific), and age (18-39 yrs, 40-59 yrs, 60+ yrs).

### 3.1.3 Pre-Participation Screening

When an exercise test is involved, the most essential safety precautions are careful pre-test screening and selection of the proper exercise test protocol in light of contraindications. Potential participants were selected according to ethnicity and age-range, and underwent pre-participation health and PA screening, either by phone or e-mail. After reading and signing the Consent Form (Appendix A, pg.230), each individual completed a Physical Activity Readiness Questionnaire (PAR-Q), revised in 1994 by the Canadian Society for Exercise Physiology (Appendix A, pg.231). The PAR-Q is a brief, self-administered medical questionnaire recognised by experts as a safe pre-exercise screening measure to identify any contraindications to exercise or exercise testing (medications that would elicit an unnatural heart rate (HR), or medical conditions that may be exacerbated).[25] The PAR-Q was evaluated and interpreted by qualified staff (author or this thesis and primary research assistant) prior to the first visit. If a participant responded 'YES' to any question on the PAR-Q, participants were asked to expand on any potential conditions or injuries they felt were a concern. In some cases, the participant's GP was telephoned to further clarify any risk to the participant. Only those participants who had minimal risk involved with submaximal exercise on a cycle ergometer were allowed to perform the test.

Participants were also screened for current level of PA in an effort to ensure the sample reflected the entire spectrum of PA activity levels (Appendix A, pg.232). PA categories are based on the current recommended guidelines (30 minutes of moderate-intensity activity at least 5 days per week) and include all dimensions of activity. Participants answered two questions assessing total time per week spent in moderate- and vigorous-intensity activities, and days per week that PAs of at least moderate-intensity were performed.

## 3.2 STUDY INTERVIEWS

Each participant required three visits within a 7- to 9-day period, and interviews were primarily conducted by the author of this thesis and the primary research assistant. Physical and physiological baseline measures were collected at the first visit, followed by 3 days of HRM. Downloading of HR data and administration of physical activity questionnaires (PAQs) was carried out on subsequent visits. The time from the recruitment of the first subject to the final measurements on the last was 8 months.

### 3.2.1 Visit 1 Protocol

The first visit took place at a local community site near the participants' residence or workplace. Full details of the visits are described in Sections 3.3, 3.4, and 3.5. Prior to any measurements, researchers explained the study aims and protocol to ensure full understanding and provide an opportunity for each participant to ask questions. Each participant was required to complete the Informed Consent Form (two copies - one for the subject to retain and one for the study records), the PAR-Q, and Current PA Screener (administered previously by phone or e-mail) (Appendix A, pgs.230-2). Contact details and health/fitness goals (optional) were also collected. Preliminary measurements of age, height, and weight were made prior to fitting of the HR monitor and gas analyser, followed by recording resting measurements of HR and blood pressure, and administering the CRF test (Section 3.5).

Subjects were given a snack and beverage following the exercise test. Verbal and written instructions were provided for the HRM period, which included cleaning, positioning and operating the monitor and receiver watch, as well as possible causes of interference. The importance of ringing the researcher with any queries or problems was stressed. Each participant signed a sign-out sheet for HRM equipment, noting the serial number, and received optional blood test forms and instructions to test for blood lipids and fasting glucose.

### 3.2.2 Heart Rate Monitoring Protocol

HRM and completion of PA logs commenced the day after Visit 1. Researchers provided a courtesy call to each subject on the first day of HRM. Subjects were instructed to wear the HR monitor and receiver watch during the waking hours of 3 consecutive days, with recording to commence immediately following the morning shower, and to end just before going to bed. Subjects were asked to complete PA Logs (Appendix A, pg.238) each day, but encouraged to record PAs as they occurred, to increase accuracy and assist recall. Further details for PAQ and PA Log data are addressed in Section 3.6.1.

In this study, Polar S-610 monitors were programmed to average and record minute-by-minute HR over a 3-day period. The validity coefficient of the correlation between EE on 3 adjacent days was reported as 0.85.[36] The HR data were downloaded using the Polar IR Infrared Serial Port Interface and Polar Precision Performance 3.0 software.

### 3.2.3 Visit 2 Protocol

Visit 2 was typically conducted the day after HRM was completed (4 days after Visit 1), at the subject's home or workplace. HR monitors and receiver watches were collected and the participant's name was crossed off the equipment sign-out sheet. In an effort to ensure all HRM activities were accounted for on the PA Logs, HR recordings were downloaded and compared to PA Logs. Detailed information for activities recorded on the PA Logs was collected so that a MET value could be assigned from the Compendium of Physical Activities.[24] Lastly, the GPAQ (WHO STEPS) (Appendix A, pg.239) and IPAQ-long (Appendix A, pg.241) were administered.

### 3.2.4 Visit 3 Protocol

The final visit occurred 3-5 days after Visit 2 (6-8 days after Visit 1), and typically took place at the participants' home. The shorter NZ instrument (NZPAQ-SF) (Appendix A, pg.245) was administered prior to the longer form (NZPAQ-LF) (Appendix A, pg.251), which was combined with questions pertaining to sport and recreation PAs from the NZSPAS (Appendix A, pg.249-52). Research staff then provided subjects with individual risk factor profiles and exercise test results from Visit 1. Finally, professional exercise prescriptions and consultations were offered as an extra benefit to subjects interested in improving their health/fitness levels.

## 3.3 PHYSICAL AND PHYSIOLOGICAL BASELINE MEASURES

During Visit 1, participants were asked to remove footwear, heavy outer clothing, and all objects from the pockets of remaining clothes for the height and weight measurements. All measures were recorded on the Visit 1 Recording Sheet (Appendix A, pg.233).

### 3.3.1 Body Mass Index

Body Mass Index (BMI) was calculated as weight (kg) divided by height ($m^2$). A stadiometer was used to measure height to the nearest 0.1 centimetre. Participants were asked to stand with feet together, arms hanging loosely by their sides, and head positioned looking straight ahead. Researchers instructed participants to distribute body weight evenly, stand with a straight back and relaxed shoulders, and ensured that participants' heels, calves, buttocks, dorsal spine and head touched the vertical frame of the stadiometer or the wall. If the researcher was shorter than the participant, a stepping stool was used to reduce the possibility of measurement error. Participants were asked to take a deep breath and stretch to their fullest height without altering their head position. The stadiometer was lowered on to the top of the participant's head until the hair was flattened, and participants carefully stepped out from under the stadiometer before the measurement was read.

A digital scale (Salter Electronic) provided body weight measurements to the nearest 0.1kg for participants under 125kg. A manual scale, which measured body weight to the nearest 0.5kg, was used for subjects greater than 125kg. Scales were placed on a hard, smooth horizontal surface for measurement. Participants were instructed to stand in the centre of the scale, with body weight evenly distributed on each foot, looking straight ahead.

### 3.3.2 Fitting of Heart Rate Monitor

Each participant was fitted with and provided a Polar S-610 HR monitor and receiver watch, and received verbal and written instructions regarding proper positioning and operation. A private area was provided for participants to position the chest strap and start the receiver watch without assistance, since they would be required to do so during the next 3 days. Researchers were available to answer any further questions and ensure the HRM equipment was positioned and functioning correctly.

### 3.3.3 Fitting of MetaMax 3B Gas Analyser

After a successful one-point calibration, participants were fitted with the appropriate-sized (small or large) face mask and body pouch. The portable gas analyser unit was arranged accordingly and secured snugly and comfortably around the participant's shoulders. It was advantageous for participants to wear the gas analyser during resting measures, as this provided ample time to adapt to the breathing apparatus and normalise breathing patterns prior to the exercise test. Exercise testing equipment is described in detail in Section 3.4.

### 3.3.4 Resting Measures

Resting Heart Rate

Resting measures were recorded while participants comfortably lay supine on a portable massage table in a dark, quiet room. Participants were instructed to relax quietly with little or no movement while researchers observed HR values via telemetry. After HR readings reached resting levels and were maintained for 5 minutes, resting heart rate (RHR) data commenced was recorded every minute for 5 minutes.

Blood Pressure

A medium or large sized cuff was chosen and connected to an automatic blood pressure (BP) monitor (Microlife BP, 3BTO-A). Two readings taken at least 5 minutes apart were used to calculate average resting BP. If the readings differed by more than 10mmHg, a third reading was taken and the two closest readings were averaged.

Fasting Blood Lipids and Glucose

Participants were provided a laboratory request form to take to their nearest community collection rooms. The blood sample required on overnight fast, and participants were instructed to eat nothing and drink only water for a minimum of eight hours beforehand. The following laboratory tests of participants' blood samples were carried out by Diagnostic Medlab, Ellerslie Laboratory, Auckland:

- Fasting Triglycerides (TG)
- Total Cholesterol (TC)
- High Density Lipoprotein (HDL)-cholesterol
- Low Density Lipoprotein (LDL)-cholesterol
- TC/HDL-cholesterol
- Fasting Glucose

Biochemical analyses were performed on the same day for fasting TG, TC, HDL-cholesterol, and glucose. Within three hours of receiving each participant's blood sample, sera were separated from the red blood cells. Fasting blood profiles for TG, TC, HDL-cholesterol, and glucose were directly quantified by enzymatic, in vitro tests using Roche automated clinical chemistry analysers. Blood lipid and glucose measures were performed by enzymatic colorimetric and UV testing, respectively. The assay method used to determine TG used a lipoprotein lipase.[152] Cholesterol esterase and cholesterol oxidase reagents were added to blood samples to determine TC and HDL-cholesterol. This assay for TC meets the 1992 National Institutes of Health (NIH) goal of less than or equal to 3% for both precision and bias.[153] Polyethylene glycol was also added for HDL-cholesterol assays, which meets the 1998 National Institutes of Health and National Cholesterol Education Program goals for acceptable performance.[154] LDL-cholesterol levels were calculated using the Friedewald formula[155]:

$$\text{LDL-cholesterol} = \text{TC} - \text{HDL-cholesterol} - (\text{TG}/2.2)$$

Fasting glucose levels were quantified by ultra-violet testing, using the hexokinase method, which is a recognised reference method.[156]

## 3.4 EQUIPMENT FOR EXERCISE TESTING

### 3.4.1 Cycle Ergometer

Refer to Section 2.3.3 for additional information pertaining to exercise test modalities. A Monark Weight Ergometer (Model 824E) was used for submaximal graded exercise tests during Visit 1. An electronic display of revolutions per minute (rpm) and assistance from a metronome enabled participants to maintain a constant pedalling rate instructed by the researchers. The flywheel travels 6 meters (m) per pedal revolution and resistance was increased by placing weights in a weight basket. Power output (Watts) for each stage of the test, was calculated using the following formula[157]:

$$\text{Watts} = \text{Force (N)} * 6 \text{ m} * \text{pedalling frequency (rpm)}$$

$$\text{where } 1 \text{ Watt} = 6.12 \text{ kg}\cdot\text{m}\cdot\text{min}^{-1}$$

### 3.4.2 Gas Analysis

The MetaMax 3B, used for direct gas analyses during rest and submaximal exercise testing, is a portable, breath-by-breath system which directly measures the oxygen ($O_2$) and carbon dioxide ($CO_2$) concentrations of inspired and expired air, HR (when a HR monitor is worn) and ventilation. The suppliers calibrated the $O_2$ and $CO_2$ analysers, the volume transducer and the pressure analyser. Prior to commencing resting measures for each participant, a one-point calibration, which automatically measured ambient air temperature, pressure, and gas concentrations, was performed by the researchers.

The reliability[158] and validity[159] of the MetaMax portable gas analysis system have been assessed. Very good agreement was found between the performance of MetaMax 3B gas sensors and a mass spectrometer.[159] Assessment of an earlier model of the MetaMax reported reliability (intra-class correlation) coefficients for $O_2$ uptake (0.984), $CO_2$ output (0.977), and minute ventilation (0.973), and concluded the equipment was reliable for exercise testing in scientific research.[158] Additional investigations into the validity of MetaMax 3B measures obtained in this study were carried out and are discussed in Section 3.6.3.

## 3.5 CARDIORESPIRATORY FITNESS LEVELS

### 3.5.1 Submaximal Exercise Testing

In the interest of safety and minimising participant burden, researchers opted for submaximal exercise testing which predicts individual levels of maximum $O_2$ consumption ($VO_{2max}$) from HR responses during increments of submaximal work rates. Although test results are less precise compared to maximal fitness tests, submaximal tests have been validated by examining correlations between directly measured $VO_{2max}$ with estimated levels from physiologic responses during submaximal exercise, as well as test performance.[25] Submaximal exercise test are more cost-effective and less time-consuming than maximal exercise tests.[25,89] Additionally, submaximal exercise testing is safer and more comfortable for subjects because individual PA and CRF levels, age, and gender are taken into consideration when designing the test protocol.[25]

In order to minimise an altered HR due to participant behaviour and diet, the following verbal and written pre-exercise test instructions were provided[25]:

- Wear comfortable, loose-fitting clothing consistent with testing.
- Drink plenty of fluids over the 24-hour period preceding the test to ensure normal hydration prior to the testing.
- Avoid food, tobacco, alcohol, and caffeine for at least 3 hours before testing.
- Avoid exercise or strenuous PA on the day of the test.
- Get an adequate amount of sleep (6 - 8 hours) the night before the test.

<u>Exercise Test Protocol</u>

The protocol for the submaximal graded exercise test on a cycle ergometer was adapted from the YMCA protocol,[160] commonly used to predict $VO_{2max}$ by extrapolating data to the individual's age-predicted $HR_{max}$.[25] Prior to exercise testing, average RHR over 5 consecutive minutes was calculated and used to determine individual target HR ranges from the following formula:

Target HR range = $[(HR_{max}-RHR)] \times \%HRR + RHR$

Where $HR_{max} = 220 - \text{age (yrs)}$, and

RHR is the individual's average HR over 5 consecutive minutes of rest, and

%HRR is the percentage of heart rate reserve, calculated as $HR_{max} - RHR$

Three protocols for determining workloads were designed according to age, gender and fitness level (Appendix A, pg.234). Each protocol included a 5-minute warm-up stage, followed by 4-minute stages at increased work rates. Additional 1-minute stage extensions were performed if steady state HR was not achieved in 4 minutes.

Average HR and $VO_2$ were measured during multiple stages of submaximal work rates designed to elicit HR responses equivalent to “moderate-” and “hard"-intensity exercise, defined by the American College of Sports Medicine (ACSM) as 40-50% and 60-70% of heart rate reserve (HRR), respectively.[25] Tests were terminated when steady-state HR was achieved during hard-intensity cycling, or by request due to unreasonable discomfort or volitional fatigue.

### 3.5.2 Ratings of Perceived Exertion

Monitoring participants’ ratings of perceived exertion (RPE) during each exercise test stage is a helpful tool for test administrators. The concept of RPE was pioneered in 1962 by G.A.V. Borg who developed a RPE scale ranging from 6 to 20, allowing subjects to subjectively rate overall exercise intensity while taking into account all sensations and feelings of physical stress, effort, and fatigue.[25]

The present study utilised a revised RPE scale, referred to as the category-ratio scale, ranging from 0 to 10 (Appendix A, pg.235). Subjective feedback on the current workload intensity provides researchers with an indication of exercise tolerance, which is useful for controlling exercise intensity during subsequent workloads and preventing early test termination. However, there is a tendency to underestimate RPE during the early and middle stages of an exercise test in approximately 5-10% of individuals.[25] In an effort to minimise misinterpretation and underreporting of the RPE scale, subjects were read standardized instructions prior to test commencement. At the end of each stage, subjects were asked to provide a verbal or visual score from the scale, which was recorded next to the associated workload.

## 3.6 DATA PROCESSING AND CONVERSIONS

### 3.6.1 Physical Activity Levels: Objective and Subjective Data

Heart Rate Monitoring Data

HR ranges, expressed as beats per minute (bpm), for moderate- and high-intensity exercise levels were classified as 40-50% and 60-70% HRR during individual calibration, using the following equation:

$\%HRR = (HR_{max} – RHR) * (\text{desired } \%) + RHR$

Where $HR_{max}$ is the individual's maximum HR, calculated by 220 – age (yrs),

And RHR is the individual's average HR over 5 consecutive minutes of rest

The HRM data were downloaded and manually searched for periods of at least 10 minutes where the individual's HR was consistently above 40%HRR. The exact duration and average HR of each PA was recorded and PA logs were verified to ensure participants had recorded a PA corresponding to that time period. If necessary, more detailed information was collected to obtain the most accurate reflection of intensity, and each PA was classified as either moderate- or vigorous-intensity, and assigned the appropriate MET value from the Compendium of Physical Activities.[24,95]

Totals from the 3-day HRM period required conversion to a 7-day total to allow for comparisons against the PAQs. Minutes of total PA, time spent during brisk walking, moderate- and vigorous-intensity activity was converted using the following calculation:

Total PA over the last 7 days (min) = (total time over 3 days (min)/3 days) * 7 days

Variation in Daily Physical Activity

The amount of within-person variation (WPV) for total PA levels was calculated as:

$WPV_i = \Sigma(x_{ij} – \text{mean } x_i)^2/2$

Where i = participant, j = day of HRM

These values were then averaged over all 186 participants to give an overall measure of variation. Taking the square root expresses the WPV as a standard deviation.

$WPV = \Sigma\ WPV_i/n$

Weekday vs. weekend variation was also examined in the 121 participants who had HRM data for both. The mean difference (min and %) of daily PA for weekdays and weekends was determined from mean daily minutes from each category.

Physical Activity Questionnaire Data

The research team was provided with procedures and coding reference manuals to assist with any potentially difficult situations during the interviews. Additionally, several training sessions were held to review proper interviewing techniques during PAQ administration. Interviewers were specifically instructed to refrain from probing participant responses, to remain neutral, and how to deal with "I don't know" responses. Each PAQ was administered one-on-one in a quiet room.

Total time spent during brisk walking, moderate- and vigorous-intensity activity during the last 7 days required aggregation of HRM data, and total values reported on the NZPAQ-LF and IPAQ-long. Brisk walking of at least moderate-intensity included all contexts (sport/recreation, transportation, and occupation), and therefore several corresponding activity codes (40, 41, 200, and 303, respectively) (Appendix A, pgs.253 and 258). These values were summed to calculate total time spent brisk walking in the last 7 days for HRM and NZPAQ-LF data.

Physical Activity Logs

PAs listed in the SPARC Showcards and previous Auckland surveys[161] were combined and condensed to create daily PA Logs for this study (Appendix A, pg.238). Participants were provided verbal and written instructions to record all PAs performed during HRM (which required at least a moderate amount of physical effort) and the approximate start time of each activity. These records were matched with HRM data where HR values were at least 40% HRR for 10 minutes or more. If HRM data revealed a period of elevated HR for which no corresponding PA was recorded on the PA logs, participants were asked to recall the activity performed during that time period. The duration and average HR of each PA was recorded on the PA Logs, and the sensitivity of PA Logs, (proportion of PAs which were accurately recalled on the NZPAQ-LF) were calculated from the following equation:

$$\% \text{ Sensitivity} = a/(a + b) * 100$$

where a is the number of PAs accurately recalled on the NZPAQ-LF

and b is the number of PAs recorded on PA Logs but not recalled on the PAQ

### 3.6.2 Calculation of Physical Activity Intensities

The associated intensity of a PA is expressed in units of METs, as multiples of the resting metabolic rate (RMR), defined as EE for an average adult sitting quietly (3.5 ml $O_2 \cdot kg^{-1} min^{-1}$).[10,24,25] Moderate- and vigorous-intensity activities are defined as 3-6 METs and > 6 METs, respectively.[24]

HRM data were examined to calculate average HR for each activity performed by each participant during HRM. MET values were derived from corresponding relative $VO_2$ ($ml \cdot kg^{-1} min^{-1}$) for each average HR, using the following calculation:

$$\text{METs} = VO_2\ (ml \cdot kg^{-1} min^{-1}) \text{ at average HR}/3.5\ ml \cdot kg^{-1} min^{-1}$$

New Zealand Compendium of Physical Activities

The Compendium of Physical Activities, developed in the United States (US) in 1993,[95] was updated in 2000,[24] and designed to facilitate coding of PAs obtained from questionnaires, interviews, diaries or logs, and to promote comparison of intensity levels. Ainsworth et al.[95] compiled the best available published and unpublished data on PA intensities, expressed as METs, and created a single coding system to classify an expansive range of PAs. Although the Compendium has been used and accepted on an international level, the activities listed were performed in a Western population and may not be appropriate for many other cultures.[8,67] Furthermore, the majority of EE data were derived from PAs performed by young adults, and have a tendency to overestimate activity intensities for middle-aged and older adults.[29]

Mean MET values for NZ activities reported and analysed during HRM were compared to published MET values from the US Compendium.[24] Subgroup analyses were performed on PAs captured at least 10 times during HRM, in an effort to examine relative PA intensities. Activities captured from the NZ population were used to create a NZ-specific compendium of PAs. The majority of Māori participants recruited through the Hoani Waititi Marae were also members of Te Roopu Manutaki, a kapahaka group in Auckland that conducts weekly practice sessions in preparation for national competitions. HRM data were used to calculate individual and group EE levels (METs) for kapahaka practices and each individual activity. HRM data from Māori participants outside of Hoani Waititi Marae, who performed the same activities, were also used in the calculations.

### 3.6.3 Cardiorespiratory Fitness Levels

A general description of the individual calibration procedure is provided in Section 2.5.2. It should be noted that because the HR vs. $VO_2$ relationship was measured during cycling, the generated calibration curves serve only as approximate representations, and more closely for activities only involving lower extremity work.

Estimation of $VO_{2max}$ from Submaximal $VO_2$ Data

Average steady state HR and $VO_2$ during the last 15 seconds of the final two minutes in each stage provided at least 3 data points to establish participants' individual calibration curves during submaximal exercise. HR and absolute $VO_2$ ($L \cdot min^{-1}$) were plotted on the y- and x-axes, respectively, and the line of best fit was extrapolated to the individual's age-predicted $HR_{max}$ (220 – age in years). The $VO_2$ value corresponding to $HR_{max}$ was regarded as the estimated, or predicted, $VO_{2max}$ (Figure 1).[25,93] Absolute values of estimated $VO_{2max}$ were converted to relative $VO_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) values, which allowed for comparison between individuals of different body sizes, and classification according to age- and gender-matched norms[25] (Tables 12 and 13).

**Figure 1.** Illustration of $VO_{2max}$ Prediction

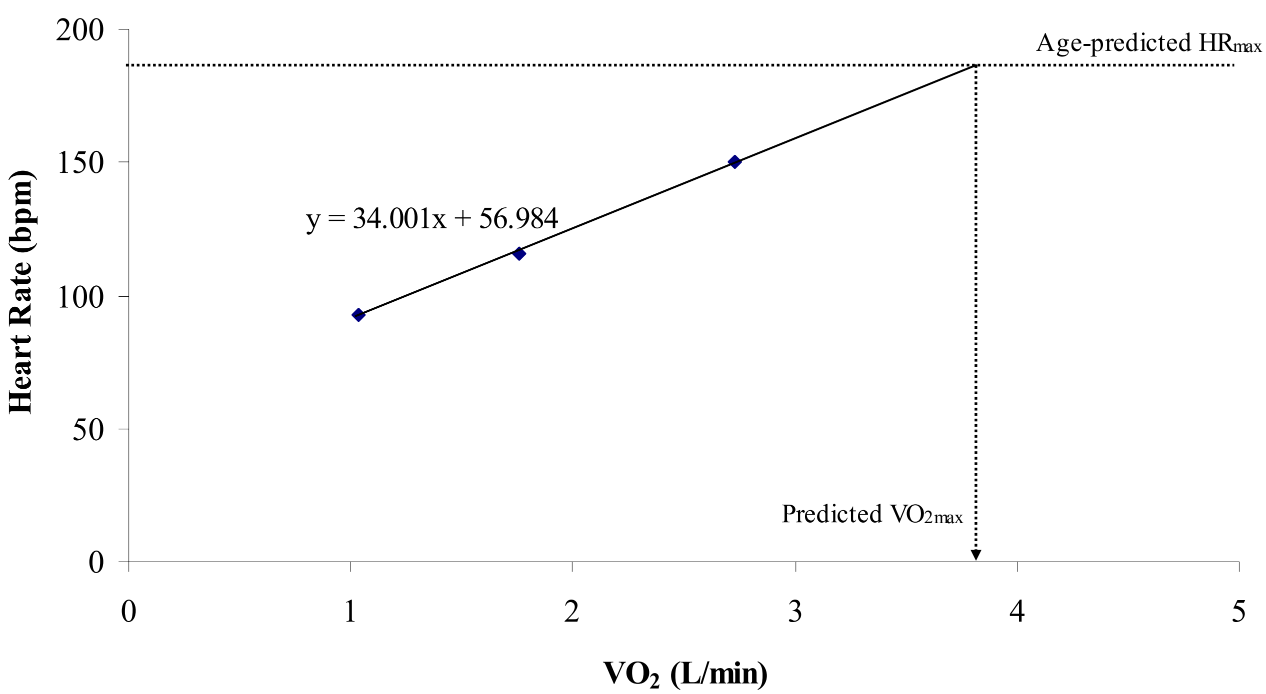


**Table 12.** Age-specific Classification of Relative Oxygen Consumption ($VO_{2max}$) - Males[25]

| | | $VO_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| **Percentile** | **Ranking** | **20-29yrs** | **30-39yrs** | **40-49yrs** | **50-59yrs** | **60+yrs** |
| 90 | Well above average | 51.4 | 50.4 | 48.2 | 45.3 | 42.5 |
| 80 | | 48.2 | 46.8 | 44.1 | 41.0 | 38.1 |
| 70 | Above Average | 46.8 | 44.6 | 41.8 | 38.5 | 35.3 |
| 60 | | 44.2 | 42.4 | 39.9 | 36.7 | 33.6 |
| 50 | Average | 42.5 | 41.0 | 38.1 | 35.2 | 31.8 |
| 40 | | 41.0 | 38.9 | 36.7 | 33.8 | 30.2 |
| 30 | Below Average | 39.5 | 37.4 | 35.1 | 32.3 | 28.7 |
| 20 | | 37.1 | 35.4 | 33.0 | 30.2 | 26.5 |
| 10 | Well below average | 34.5 | 32.5 | 30.9 | 28.0 | 23.1 |

**Table 13.** Age-specific Classification of Relative Oxygen Consumption ($VO_{2max}$) - Females[25]

| | | $VO_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| **Percentile** | **Ranking** | **20-29yrs** | **30-39yrs** | **40-49yrs** | **50-59yrs** | **60+yrs** |
| 90 | Well above average | 44.2 | 41.0 | 39.5 | 35.2 | 35.2 |
| 80 | | 41.0 | 38.6 | 36.3 | 32.3 | 31.2 |
| 70 | Above Average | 38.1 | 36.7 | 33.8 | 30.9 | 29.4 |
| 60 | | 36.7 | 34.6 | 32.3 | 29.4 | 27.2 |
| 50 | Average | 35.2 | 33.8 | 30.9 | 28.2 | 25.8 |
| 40 | | 33.8 | 32.3 | 29.5 | 26.9 | 24.5 |
| 30 | Below Average | 32.3 | 30.5 | 28.3 | 25.5 | 23.8 |
| 20 | | 30.6 | 28.7 | 26.5 | 24.3 | 22.8 |
| 10 | Well below average | 28.4 | 26.5 | 25.1 | 22.3 | 20.8 |

The HR and $VO_2$ values from each stage were plotted in Microsoft Excel, which generated a line of best fit (y = mx + b), and absolute $VO_2$ was calculated using the equation:

$$VO_2 = (HR_{max} - b) \cdot m^{-1}$$

where m = the slope and b = the intercept of the HR vs. $VO_2$ relationship

Relative $VO_2$ was calculated in Microsoft Excel with the following equation:

$$V0_2\,(ml \cdot kg^{-1} \cdot min^{-1}) = (VO_2 \text{ in } L \cdot min^{-1} * 1{,}000)/BM$$

where BM = body mass in kg

Measured relative $VO_2$ levels were compared to predicted values calculated by the following 2 equations used for predicting the oxygen cost of leg cycle ergometry:

ACSM[25]: $V0_2\,(ml \cdot kg^{-1} \cdot min^{-1}) = (10.8 * W * BM^{-1}) + 7$

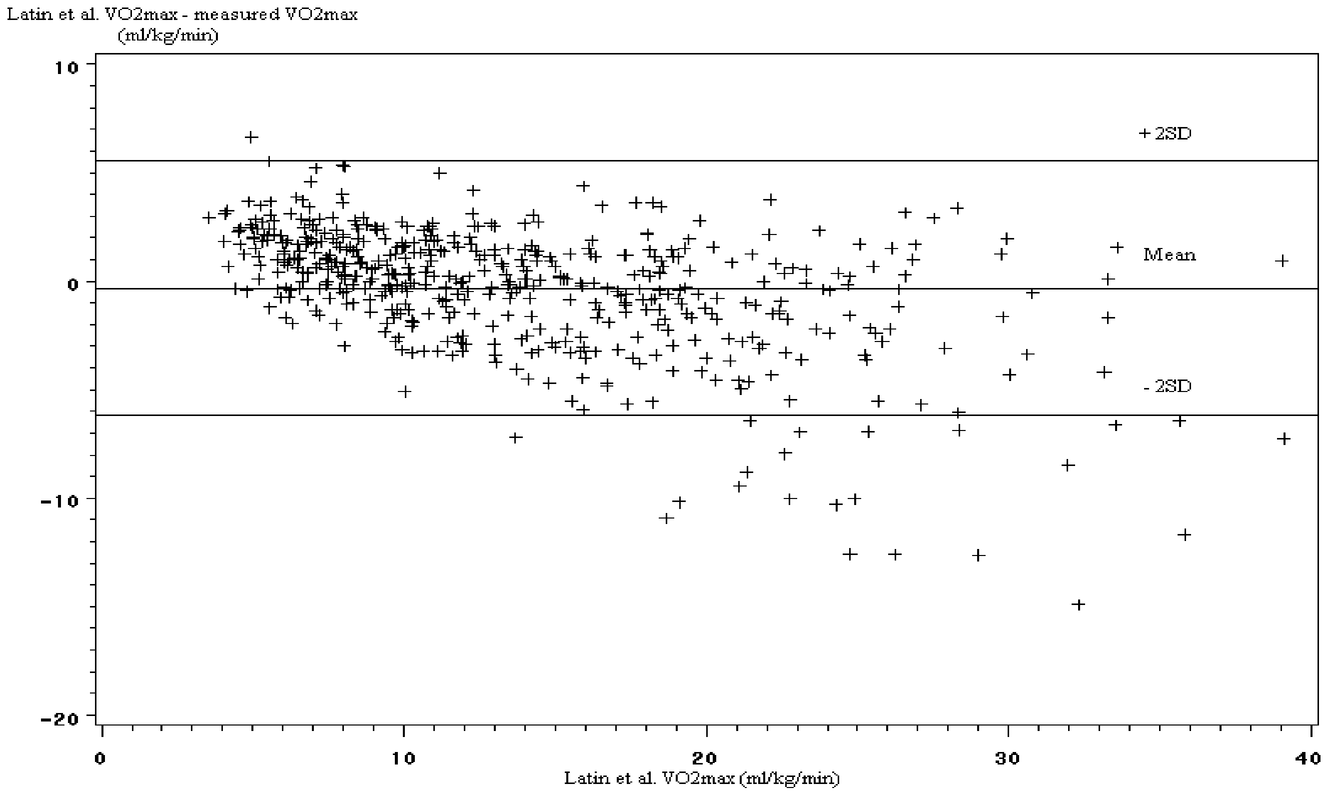
Latin[162]: $V0_2\,(ml \cdot kg^{-1} \cdot min^{-1}) = (0.35 + 0.0113*W) * (1{,}000/BM)$

where W = power expressed as Watts, BM = body mass in kg

The Latin equation was created and validated as a result of criticism surrounding consistent under-prediction of $VO_{2max}$ from the ACSM equation. , and a new equation.[162] The new equation contains a slightly lower slope and has an intercept based on an estimation of resting metabolism plus an additional 260 ml, which is believed to reflect the $O_2$ cost of unloaded cycling. The new equation was more exact at each power output, particularly with respect to total error and mean difference.[162]

Measured $VO_2$ from this sample was better matched with predicted VO2 values using the Latin equation. A Bland-Altman plot (Figure 2) was created to further examine limits of agreement (± 2SD) between measured and predicted $VO_2$ values. Five participants encountered slippage of the brake lacing, which decreased flywheel tension, consequently requiring extremely high workloads to attain the desired HR at each stage. These participants' data were excluded because accurate workloads could not be determined. A mean difference of -0.32 $ml \cdot kg^{-1} \cdot min^{-1}$ between measured $VO_2$ and predicted $VO_{2max}$ suggests measured values were slightly lower than predicted. Furthermore, data points below the -2SD limit of agreement illustrate that, for a proportion of participants with $VO_{2max}$ levels above ~20 $ml \cdot kg^{-1} \cdot min^{-1}$, measured values were substantially higher than predicted values.

**Figure 2.** Bland Altman plot comparing Measured and Predicted $VO_2$ values[162]



## 3.7 METHODS OF ANALYSES FOR PHYSICAL ACTIVITY QUESTIONNAIRES

Participants were classified according to PA definitions, specific to the analysis method used. PA frequency was reported as days per week "active" (defined as 30 minutes or more of moderate-intensity activity, including brisk walking, or 15 minutes or more of vigorous-intensity activity). The percentage of the sample meeting current PA guidelines in terms of duration alone, and duration and frequency combined were calculated.

The following comparisons were made:

1) NZPAQ-SF and NZPAQ-LF vs. HRM (Analyses 1-4) to determine the validity of each questionnaire.
2) NZPAQ-SF vs. NZPAQ-LF (Analysis 1) to assess the robustness of the former.
3) NZPAQ-SF and NZPAQ-LF vs. NZSPAS (Analysis 1) to assess comparability with previous Hillary Commission surveys.
4) NZPAQ-SF and NZPAQ-LF vs. IPAQ-long (Analyses 1-4) to assess comparability with international surveys.
5) IPAQ-long vs. HRM (Analyses 1-4) to determine the validity in NZ by HRM

Comparisons 1 and 3 were further analysed by age, gender, and ethnicity (Appendix B1-8, pg.275). Due to time constraints, only data pertaining to smoking habit was utilised from the WHO STEPS instrument (GPAQ).

### 3.7.1 Analysis 1

Frequency and duration of brisk walking, moderate- and vigorous-intensity activities reported on the NZPAQ-SF and NZPAQ-LF were summed to determine total minutes of at least moderate-intensity activity (including transport, occupation, sport/recreational, and incidental). Total activity during the last 7 days was categorised by the following definitions[105]:

- Relatively Inactive – less than 2.5 hours
- Relatively Active – at least 2.5 hours, but less than 5 hours
- Highly Active – 5 hours or more

Theoretically, Analysis 1 is the preferred method for determining PA levels, as the calculations and PA definitions are straight-forward and without any major assumptions.

### 3.7.2 Analysis 2

The calculations and PA definitions for Analysis 2 are identical to those involved in Analysis 1. However, this method of analysis assumes 1 minute of vigorous-intensity activity is equivalent to 2 minutes of moderate-intensity activity. This is the preferred analysis by SPARC, as the behaviour change question on the NZPAQ-SF and NZPAQ-LF advises respondents to make this conversion.

### 3.7.3 Analysis 3

Analysis 3 followed a draft of guidelines[163] recently created to analyse a different self-administered questionnaire, the IPAQ-short, and reports PA in MET-min per week for the last 7 days. Definitions for PA categories, listed below, include multiple criteria for classification based on combinations of frequency, duration, intensity, and MET-min. The following analyses, specific to the IPAQ-short PAQ, were carried out:

- Insufficiently Active (Category 1): Individuals who do not meet criteria for Categories 2 or 3.
- Sufficiently Active (Category 2): 3 or more days of vigorous activity of at least 20 min/day, *OR* 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day, *OR* 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week.
- Highly Active (Category 3): vigorous-intensity activity on at least 3 days achieving a minimum of at least 1,500 MET-min/week, *OR* 7 or more days of any combination of walking, moderate- or vigorous-intensity activities achieving a minimum of at least 1,500 MET-min/week.

### 3.7.4 Analysis 4

Although PA and energy expenditure (EE) are not synonymous,[23] activity recommendations are also provided in terms of daily or total energy expenditure (TEE).[3,10,25,69] Total PA was converted to total EE (kcals/week) for the last 7 days (EE = Weight * METs * (Duration/60).[95] This value corresponds only to the energy costs of PAs captured during HRM and is not a reflection of total daily EE. MET-minutes per week were calculated using the mean MET values for each activity, as described in Analysis 3,[163] and the sample was categorised according to recommended weekly EE values from the ACSM.[25] In theory, Analysis 4 is the preferred method for determining PA levels for the purpose of weight-loss/maintenance. Although recommended ranges of EE levels vary,[10,25] it is well-recognised that an increase in daily EE is associated with substantial health benefits.[3,96]

## 3.8 STATISTICAL METHODS

The data were analysed using the SAS statistical package. CRF and HR data were collected as continuous measures, used to estimate $VO_{2max}$ and TEE, respectively. Multiple linear regression analyses were used to adjust for confounding associated with CRF and CV risk factors. PAQs collected data as continuous and categorical variables. The means (95% CI) and proportion of participants in each activity category were reported for the total sample and by age, ethnicity, and gender, using the physiological measure of HRM as the 'gold standard'. A range of statistical methods was used including comparisons of means using factorial analyses, Spearman's correlation coefficients (r) and weighted kappa (κ) between subgroups.[146] Correlation coefficients were classified as poor ($r<0.30$), moderate ($r=0.31$-$0.50$) and strong ($r>0.50$).[164] The magnitudes of disagreement between mean PA levels assessed by HRM and recalled on the NZPAQs were estimated statistically by the Bland-Altman method.[148]

### 3.8.1 Research Hypotheses

Hypotheses for this research study are listed below. The null hypotheses examined in this thesis are:

- No relationship exists between CRF and the following CV risk factors (BMI, SBP, DBP, TG, HDL-cholesterol, LDL-cholesterol, TC, TC/HDL-cholesterol ratio, fasting glucose)
- No relationship exists between PA and the following CV risk factors (BMI, SBP, DBP, TG, HDL-cholesterol, LDL-cholesterol, TC, TC/HDL-cholesterol ratio, fasting glucose)
- Physical activity levels reported on the NZPAQ-SF, NZPAQ-LF, and the IPAQ-long are not different to those measured by HRM.
- Physical activity levels reported on the NZPAQ-SF and NZPAQ-LF are not different to each other, or to those reported on the NZSPAS.

# CHAPTER 4

# RESULTS

This chapter presents cross-sectional data on the demographic, physical and physiological characteristics of the study sample, and estimated physical activity (PA) and cardiorespiratory fitness (CRF) levels. Results from the validation of New Zealand and international physical activity questionnaires (NZPAQs and IPAQ-long, respectively) against heart rate monitoring (HRM) are described, followed by participant recall of PA mode and intensity. Next, a NZ-specific compendium of PAs, listing the intensity levels of all PAs performed during HRM, is reported. Lastly, multiple linear regression models analysing correlates of CRF are presented, while associations between PA and CRF with cardiovascular (CV) risk factors are also reported.

## 4.1 DEMOGRAPHIC, PHYSICAL AND PHYSIOLOGICAL CHARACTERISTICS

This section describes the sample characteristics in an effort to identify any statistically significant differences. The total sample (N=186) by age, ethnicity and gender is presented in Table 14. Descriptive characteristics and physiological measures of the study sample and gender, ethnicity and age subgroups are shown in Tables 15, 16 and 17, respectively. The proportion of participants classified as overweight and obese are presented in Table 18. Overall, the total sample had a mean age of 48.6 yrs, and a mean blood pressure (BP) of 127/79 mmHg. Approximately 36% and 40% of the total sample was classified as overweight and obese, respectively. Height ($p<0.0001$) and weight ($p=0.001$) were the only observed gender differences that reached statistical significance, as males were taller and heavier than females. Although the proportion of male smokers (27%) was higher than females (16%), this difference was not statistically significant ($p=0.07$).

The 60 European/Other participants were primarily of European descent (n=50). However, the remaining 10 participants represented the following 'other' ethnic groups: 3 Chinese, 1 Burmese, 1 Filipino, 1 Sri Lankan, 2 Latin American, 1 Hispanic, and 1 Iranian. In general, European/Other participants displayed significantly lower body weight and body mass index (BMI) values ($p<0.0001$), compared to Māori and then Pacific, and significantly lower BP levels compared to the Pacific sample. Pacific and Māori participants had the highest rates of obesity (55% and 44%, respectively), compared to European/Other participants (18%), and rates of obesity were greatest for Māori (43%), followed by

Pacific (32%) and European/Other (32%) participants. Compared to the 18-39 yrs age group, participants in the 40-59 yrs and 60+ yrs age groups showed significantly higher systolic blood pressure (SBP) (p=0.008 and p=0.0004, respectively) and diastolic blood pressure (DBP) (p=0.0002 and p=0.0005, respectively). Additionally, the 60+ yrs age group was significantly shorter than the 18-39 yrs (p=0.003) and 40-59 yrs (p=0.01) age groups.

**Table 14.** Study Sample (N=186) by Age, Ethnicity and Gender

| **Age-Group (yrs)** | **European/Other** | | **Māori** | | **Pacific** | | **Total** | |
|---|---|---|---|---|---|---|---|---|
| Gender: | M | F | M | F | M | F | M | F |
| 18-39 | 10 | 10 | 10 | 10 | 9 | 13 | 29 | 33 |
| 40-59 | 10 | 10 | 10 | 11 | 11 | 11 | 31 | 32 |
| 60+ | 10 | 10 | 10 | 10 | 10 | 11 | 30 | 31 |
| Total | 30 | 30 | 30 | 31 | 30 | 35 | 90 | 96 |

**Table 15.** Characteristics of Total Sample (N=186) and by Gender

| | **Mean (95% CI)** | | | |
|---|---|---|---|---|
| | **Total N=186** | **Male (M) N=90** | **Female (F) N=96** | **M vs. F p-value** |
| Age (yrs) | 48.6 (46.2, 51.0) | 48.4 (45.1, 51.7) | 48.7 (45.5, 52.0) | P = 0.88 |
| Height (cm) | 169.2 (167.9, 170.5) | 174.7 (173.1, 176.3) | 164.1 (162.7, 165.4) | p < 0.0001 |
| Weight (kg) | 87.4 (84.4, 90.4) | 92.5 (88.5, 96.5) | 82.6 (78.4, 86.8) | p = 0.001 |
| BMI ($kg{\cdot}m^{-2}$) | 30.4 (29.5, 31.3) | 30.2 (29.0, 31.4) | 30.6 (29.2, 32.0) | P = 0.61 |
| Resting HR (bpm) | 62.2 (61.0, 63.4) | 61.2 (59.4, 63.0) | 63.1 (61.5, 64.7) | P = 0.12 |
| Systolic BP (mmHg) | 126.8 (124.0, 129.6) | 129.6 (126.8, 132.4) | 124.2 (119.4, 129.0) | P = 0.06 |
| Diastolic BP (mmHg) | 78.5 (76.6, 80.4) | 79.4 (77.1, 81.7) | 77.6 (74.6, 80.6) | P = 0.36 |
| Smoking Habit (%) | 21.0 (15.4, 27.5) | 26.7 (17.9, 37.0) | 15.6 (9.0, 24.5) | p = 0.07 |

**Table 16.** Characteristics of Total Sample by Ethnicity

| | Mean (95% CI), p-value compared with Euro | | | | |
|---|---|---|---|---|---|
| | **Euro/Other n=60** | **Māori N=61** | **p-value** | **Pacific n=65** | **p-value** |
| Age (yrs) | 47.1 (42.7, 51.5) | 49.9 (45.7, 54.1) | 0.35 | 48.7 (44.9, 52.5) | 0.60 |
| Height (cm) | 169.8 (167.7, 171.9) | 168.2 (165.7, 170.7) | 0.32 | 169.7 (167.6, 171.8) | 0.90 |
| Weight (kg) | 75.3 (71.4, 79.2) | 90.3 (85.5, 95.1) | < 0.0001 | 95.8 (90.7, 100.9) | < 0.0001 |
| BMI ($kg \cdot m^{-2}$) | 26.0 (24.7, 27.3) | 31.8 (30.4, 33.2) | < 0.0001 | 33.2 (29.2, 37.2) | < 0.0001 |
| Resting HR (bpm) | 60.5 (58.6, 62.4) | 62.5 (60.1, 64.9) | 0.19 | 63.5 (61.5, 65.5) | 0.045 |
| Systolic BP (mmHg) | 121.7 (116.7, 126.7) | 125.8 (120.4, 131.2) | 0.25 | 132.5 (128.5, 136.5) | 0.002 |
| Diastolic BP (mmHg) | 75.4 (71.9, 78.9) | 78.9 (75.3, 82.5) | 0.14 | 80.9 (78.2, 83.6) | 0.02 |
| Smoking Habit (%) | 20.0 (10.8, 32.3) | 21.3 (11.9, 33.7) | 0.86 | 21.5 (12.3, 33.5) | 0.83 |

**Table 17.** Characteristics of Total Sample by Age Groups

| | Mean (95% CI), p-value compared with 18-39 yrs | | | | |
|---|---|---|---|---|---|
| | **18-39yrs n=64** | **40-59yrs n=60** | **p-value** | **60+yrs n=62** | **p-value** |
| Age (yrs) | 30.1 (28.8, 31.4) | 49.0 (47.5, 50.5) | -- | 67.2 (65.7, 68.7) | -- |
| Height (cm) | 171.0 (168.9, 173.1) | 170.4 (168.2, 172.6) | 0.68[a] | 166.3 (164.1, 168.5) | 0.003[a] 0.01[b] |
| Weight (kg) | 86.4 (80.8, 92.0) | 90.9 (85.8, 96.0) | 0.23[a] | 85.0 (80.3, 89.7) | 0.70[a] 0.12[b] |
| BMI ($kg \cdot m^{-2}$) | 29.4 (27.6, 31.2) | 31.0 (29.5, 32.5) | 0.18[a] | 30.8 (29.2, 32.4) | 0.24[a] 0.87[b] |
| Resting HR (bpm) | 60.1 (57.7, 62.5) | 63.5 (61.5, 65.5) | 0.09[a] | 62.3 (60.5, 64.1) | 0.37[a] 0.44[b] |
| Systolic BP (mmHg) | 119.7 (117.2, 122.2) | 129.0 (125.8, 132.2) | 0.008[a] | 132.1 (124.9, 139.3) | 0.0004[a] 0.37[b] |
| Diastolic BP (mmHg) | 73.0 (70.9, 75.1) | 81.6 (79.2, 84.0) | 0.0002[a] | 81.1 (76.6, 85.6) | 0.0005[a] 0.82[b] |
| Smoking Habit (%) | 21.9 (12.5, 34.0) | 28.3 (17.5, 41.4) | 0.38[a] | 12.9 (5.7, 23.9) | 0.22[a] 0.04[b] |

a) compared with 18-39 yrs, b) compared with 40-59 yrs

**Table 18.** Rates of Overweight and Obesity in Study Sample by Age, Ethnicity and Gender

| Subgroup | N | Overweight[1] (%) | Obese[2] (%) |
|---|---|---|---|
| Total Sample | 186 | 35.5 | 39.8 |
| **Age** | | | |
| 18-39 yrs | 64 | 28.1 | 35.9 |
| 40-59 yrs | 60 | 39.3 | 43.3 |
| 60+ yrs | 62 | 40.3 | 40.3 |
| **Ethnicity** | | | |
| Euro/Other | 60 | 31.7 | 18.3 |
| Māori | 61 | 42.6 | 44.3 |
| Pacific | 65 | 32.3 | 55.4 |
| **Gender** | | | |
| Males | 90 | 40.0 | 37.8 |
| Females | 96 | 31.3 | 41.7 |

[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

### 4.1.1 Physical Activity Levels

Six participants (3 male, 3 female) had unusable heart rate (HR) data for various reasons. HR monitors were unable to detect one participant's HR (Māori male aged 60+ yrs), despite 2 separate attempts. Two Māori participants (1 male and 1 female, both aged 60+ yrs) had abnormally high HR readings throughout all 3 days of HRM, and HR data was lost for 3 European/Other participants (1 male aged 40-59 yrs, 2 females aged 18-39 yrs) due to computer problems.

<u>Daily Variation of Physical Activity</u>

Total time spent in brisk walking, moderate- and vigorous-intensity PA over the 3-day HRM period was summed to calculate 3-day total PA levels and examine daily variation within this sample and by subgroup (Table 19). Overall, the total sample performed an average of 100.0 minutes of at least moderate-intensity PA, with a mean daily variation of 50.0 min/day. Subgroup analyses showed 60+ yrs, European/Other, and male participants had higher levels of 3-day total PA. The magnitude of variation was greatest between ethnic groups, as the European/Other and Pacific participants displayed the lowest (44.0 min/day) and highest (61.6 min/day) levels of variation in PA, respectively.

**Table 19.** Duration and Daily Variation of Physical Activity by Age, Ethnicity, and Gender

| **Subgroup** | **N** | **Mean PA Duration (min) During HRM** | | **Mean Daily Variation* During HRM** | |
|---|---|---|---|---|---|
| | | **3-day** | **Daily** | **Min/Day** | **%** |
| Total Sample | 180 | 100.0 | 33.3 | 50.0 | 50.0 |
| **Age** | | | | | |
| 18-39 yrs | 62 | 72.9 | 24.3 | 39.1 | 53.6 |
| 40-59 yrs | 59 | 101.7 | 33.9 | 50.3 | 49.5 |
| 60+ yrs | 59 | 126.5 | 42.2 | 59.2 | 46.8 |
| **Ethnicity** | | | | | |
| Euro/Other | 57 | 132.7 | 44.2 | 58.4 | 44.0 |
| Māori | 58 | 98.9 | 33.0 | 46.9 | 47.4 |
| Pacific | 65 | 72.1 | 24.0 | 44.4 | 61.6 |
| **Gender** | | | | | |
| Males | 87 | 113.1 | 37.7 | 55.2 | 48.8 |
| Females | 93 | 87.6 | 29.2 | 44.6 | 50.9 |

* calculated from equation on pg.95

Weekday vs. Weekend Variation of Physical Activity

A total of 121 participants from this study had both weekday and weekend HRM data, which was examined to determine if differences existed. Mean weekday and weekend PA levels were 31.2 and 33.9 min/day, respectively, the equivalent of a 9% difference (p=0.02).

### 4.1.2 Cardiorespiratory Fitness Levels

Estimated relative CRF levels, expressed as maximum oxygen consumption ($VO_{2max}$), for the total sample and all subgroups are shown in Table 20. Expressing $VO_{2max}$ in relative terms ($ml \cdot kg^{-1} \cdot min^{-1}$) accounts for differences in body size, and is the preferred value for group comparisons. Relative $VO_{2max}$ was significantly higher for the 18-39 yrs age group compared to participants aged 40-59 yrs ($p<0.0001$) and 60+ yrs ($p<0.0001$). European/Other and male participants displayed significantly higher relative $V0_{2max}$ estimates, compared to Māori ($p=0.02$) and Pacific ($p=0.0002$) and female ($p<0.0001$) participants, respectively.

<u>Correlates of Cardiorespiratory Fitness Levels</u>

Multiple regression models examining the relationship between CRF, represented as predicted $VO_{2max}$, and CV risk factors are presented in Table 21. Gender, ethnicity, obesity, and participation in vigorous-intensity PA were all found to be significant correlates of $VO_{2max}$ levels. Male and European/Other participants demonstrated significantly higher $VO_{2max}$ levels compared to female ($p<0.001$), Māori ($p<0.05$) and Pacific ($p<0.001$) participants, respectively. Adding BMI to the base model greatly decreased the ethnicity coefficients (Model 2), indicating that ethnic differences in obesity explain approximately half of the ethnic differences in $VO_{2max}$. Similarly, vigorous-intensity PA (>15 min/day) (Model 3) was significantly related to $VO_{2max}$, as ethnic differences associated with $VO_{2max}$ decreased. Smoking habit (Model 4) had almost no effect on the base model, and was therefore omitted from further models. Adjusting for BMI, moderate- and vigorous-intensity PA increased the base model $R^2$ from 0.15 to 0.23, and decreased gender differences slightly, while ethnic differences decreased dramatically.

**Table 20.** Estimated Relative $VO_{2max}$ Levels by Age, Ethnicity, and Gender

| | | **Mean Cardiorespiratory Fitness Level (95% CI)** | | | |
|---|---|---|---|---|---|
| **Subgroup** | **N** | **Est. $VO_{2max}$ ($L \cdot min^{-1}$)** | **p-value** | **Est. $VO_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)** | **p-value** |
| Total Sample | 186 | 2.31 (2.2, 2.4) | -- | 27.9 (26.2, 29.6) | -- |
| **Age** | | | | | |
| 18-39 yrs | 64 | 2.78 (2.5, 3.0) | * | 32.9 (30.7, 35.1) | * |
| 40-59 yrs | 60 | 2.39 (2.2, 2.6) | 0.0096 | 26.8 (24.6, 29.0) | 0.002 |
| 60+ yrs | 62 | 1.76 (1.6, 1.9) | < 0.0001 < 0.0001[a] | 23.9 (20.3, 27.5) | < 0.0001 0.15[a] |
| **Ethnicity** | | | | | |
| Euro/Other | 60 | 2.39 (2.2, 2.6) | * | 32.1 (30.0, 34.2) | * |
| Māori | 61 | 2.37 (2.1, 2.6) | 0.90 | 27.5 (24.7, 30.3) | 0.02 |
| Pacific | 65 | 2.19 (1.9, 2.4) | 0.21 | 24.5 (21.3, 27.7) | 0.0002 |
| **Gender** | | | | | |
| Males | 90 | 2.77 (2.6, 3.0) | * | 31.4 (29.1, 33.7) | * |
| Females | 96 | 1.89 (1.8, 2.0) | p < 0.0001 | 24.7 (22.4, 27.0) | p < 0.0001 |

* = reference category for p-value, a) compared with 40-59 yrs
Est. $VO_{2max}$ = Estimated maximal oxygen consumption expressed in absolute ($L \cdot min^{-1}$) and relative ($ml \cdot kg^{-1} \cdot min^{-1}$) units

**Table 21.** Regression Models showing Correlates of Cardiorespiratory Fitness (N=186)

| | Model | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | $R^2$ | 0.15 | 0.21 | 0.18 | 0.15 | 0.23 |
| | | **Mean difference in $ml \cdot kg^{-1} \cdot min^{-1}$ (SE)** | | | | |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- |
| | Māori | -4.6 (2.0)* | -2.2 (2.0) | -4.1 (2.0)* | -4.6 (2.0)* | -1.8 (2.1) |
| | Pacific | -7.4 (1.9)*** | -4.5 (2.0)* | -6.5 (2.0)** | -7.4 (1.9)*** | -3.8 (2.1) |
| Gender | Male | 6.5 (1.6)*** | 6.6 (1.5)*** | 6.0 (1.6)*** | 6.6 (1.6)*** | 6.1 (1.6)*** |
| | Female | -- | -- | -- | -- | -- |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | -7.6 (2.2)*** | | | -7.1 (2.2)** |
| | Overweight[2] | | -3.7 (2.1) | | | -3.0 (2.2) |
| | Normal | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | -0.1 (1.9) | | 0.1 (1.9) |
| | 30-60 | | | -0.6 (2.0) | | -0.5 (2.0) |
| | < 30 | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | 4.1 (1.9)* | | 3.6 (1.8) |
| | 1-15 | | | 1.2 (2.4) | | 1.8 (2.3) |
| | 0 | -- | -- | -- | -- | -- |
| Smoking | Yes | | | | -0.7 (2.0) | |
| | No | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category
[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

## 4.2 VALIDATION OF PHYSICAL ACTIVITY QUESTIONNAIRES

Correlations between physical activity questionnaires (PAQs) and HRM were examined to determine the validity of each instrument for the New Zealand (NZ) population. Four different methods of analyses were used to determine the frequency and total duration of brisk walking, moderate- and vigorous-intensity activities reported for the last 7 days on the short and long NZ instruments (NZPAQ-SF and NZPAQ-LF, respectively, and the IPAQ-long. The proportion of participants meeting current PA guidelines in terms of duration alone, and duration and frequency combined were also calculated. General reviews of the four analyses are provided below. Detailed descriptions of each analysis are in Section 3.7.

- Analysis 1: total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.
- Analysis 2: total minutes of brisk walking, moderate- and vigorous-intensity PA were summed. However, 1 minute of vigorous-intensity activity was equivalent to 2 minutes of moderate-intensity activity.
- Analysis 3: this analysis is specific to shorter versions of the IPAQ-long, and determined total PA over the last 7 days in terms of MET-minutes per week.
- Analysis 4: total minutes of brisk walking, moderate- and vigorous-intensity PA were converted to total EE (kcals/week) over the last 7 days

### 4.2.1 NZPAQ-SF and NZPAQ-LF vs. HRM

Validation analyses 1, 2, 3 and 4 for the entire sample are shown in Tables 22, 23, 24, and 25, respectively. Main findings are summarised in Table 26. Subgroup analyses for the NZPAQs vs. HRM are shown in Appendices B1-4, pg.275.

<u>Analyses 1-4 vs. Heart Rate Monitoring</u>

Self-reported PA levels were substantially overestimated on NZPAQ-SF and NZPAQ-LF, compared to HRM. Bland-Altman plots enabled further analyses of the relationship between self-reported PA and HRM. Activity levels (Analysis 1) were generally overestimated by physically inactive participants, and underestimated by highly active participants on the NZPAQ-SF (Figure 3) and NZPAQ-LF (Figure 4). All analyses demonstrated similar trends, and the magnitude of disagreement was highest for the physically inactive participants. Although total activity levels in Analyses 2, 3, and 4 were better correlated with HRM compared to Analysis 1, the correlations were small (Table 26). Brisk walking and vigorous-intensity PA reported on the NZPAQ-LF were more strongly correlated with HRM in all 4 analyses, compared to the NZPAQ-SF. No significant correlations existed between moderate-intensity activity and HRM.

Physical Activity Categories and Current Recommendations

Categories of PA levels were better correlated to HRM using Analyses 2 and 4, although both correlations were considered poor (Table 26). The proportions of the sample meeting current PA guidelines, either by duration alone or by duration and frequency, are poorly correlated with HRM.

Subgroup Analyses

Brisk walking, as reported on the NZPAQ-LF, presented a more accurate reflection of HRM values for all subgroups, compared to the NZPAQ-SF (Appendices B1-4, pg.275). Although each age group overestimated total activity levels, the highest correlation to HRM was observed in the 18-39 yrs age group. Additionally, the 18-39 yrs age group was the only subgroup to show a statistically significant correlation for moderate-intensity activity on the NZPAQ-SF, as well as a moderate correlation with HRM for the proportion of individuals meeting current PA recommendations. The 60+ yrs group showed the poorest correlation to HRM. Self-reported PA was highest for this group, particularly on the NZPAQ-SF, but HRM activity levels were the lowest. Total activity on both PAQs, in the 40-59 yrs age group, was significantly correlated to HRM using Analysis 2 (Appendix B2, pg.283). A stronger correlation for total activity was seen on both PAQs, for all ethnic groups and both genders, compared to moderate-intensity PA. However, this correlation was only statistically significant for European/Others. Total activity calculated for males and females (Analysis 2) was significantly correlated to HRM from the NZPAQ-LF and NZPAQ-SF, respectively.

Self-reported PA for European/Others was more strongly and significantly associated with HRM values on both questionnaires, compared to Pacific and Māori. Brisk walking was the only activity component that was significantly correlated to HRM for the Māori (NZPAQ-LF only) and Pacific groups (both NZPAQs), and vigorous-intensity activity was significantly correlated for the Pacific group (NZPAQ-LF only). Although a statistically significant correlation was seen in brisk walking for males and females on both questionnaires, the correlation was stronger for the NZPAQ-LF. Vigorous-intensity activity was significantly correlated for males on both questionnaires, and for females on the NZPAQ-LF. Similarly, associations were larger on the NZPAQ-LF.

**Table 22.** NZPAQ-SF and NZPAQ-LF vs. HRM - Analysis 1*

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **HRM N=180** |
| Brisk Walking | 122.7 (81.3, 164.1) | 89.0 (66.6, 111.4) | 31.9 (19.3, 44.5) |
| Moderate | 271.5 (180.9, 362.1) | 313.7 (252.6, 374.8) | 114.6 (78.4, 150.8) |
| Vigorous | 105.5 (80.6, 130.4) | 79.3 (61.4, 97.2) | 46.7 (28.5, 64.9) |
| Total | 499.7 (392.8, 606.6) | 481.9 (409.7, 554.1) | 193.1 (150.5, 235.7) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with HRM, p-value** | | |
| Brisk Walking | 0.27, p = 0.0003 | 0.43, p < 0.0001 | **--** |
| Moderate | 0.07, p = 0.34 | 0.02, p = 0.81 | **--** |
| Vigorous | 0.27, p = 0.003 | 0.35, p < 0.0001 | **--** |
| Total | 0.18, p = 0.01 | 0.19, p = 0.01 | **--** |
| **Activity Category** (total time over last 7 days) | **% in Activity Groups (n=180)** | | |
| Relatively Inactive: < 2.5 hours | 27.8 | 25.0 | 58.9 |
| Relatively Active: 2.5 to 5 hours | 21.7 | 21.1 | 20.6 |
| Highly Active: ≥ 5 hours | 50.6 | 53.9 | 20.6 |
| Weighted Kappa vs. HRM | 0.15 | 0.13 | -- |
| **Current NZ Guidelines**[6] | **% Meeting Current Recommendations** | | |
| ≥ 30 min/day on ≥ 5 days | 35.0 | 19.9 | 5.4 |
| ≥ 150 min/week, < 5 days | 38.2 | 32.8 | 34.4 |
| Weighted Kappa vs. HRM | 0.12 | 0.10 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**Figure 3.** NZPAQ-SF vs. HRM: Agreement of Self-reported and Objective Measures of Physical Activity Duration

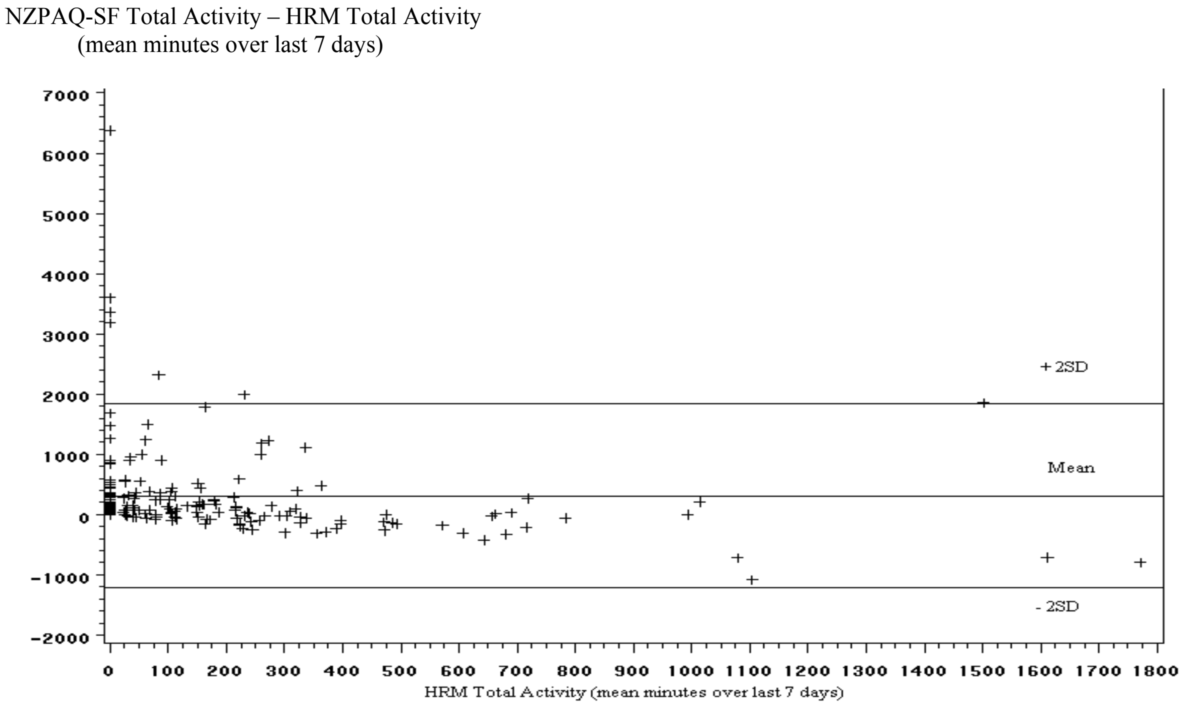



**Figure 4.** NZPAQ-LF vs. HRM: Agreement of Self-reported and Objective Measures of Physical Activity Duration

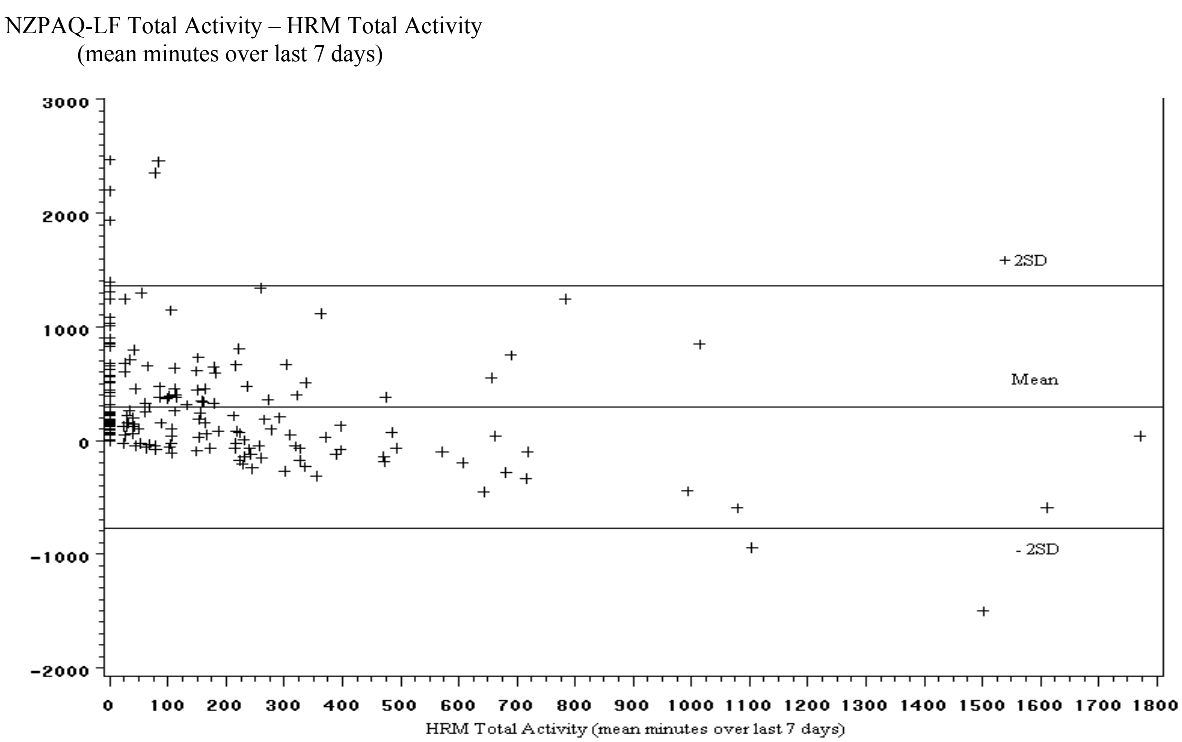


**Table 23.** NZPAQ-SF and NZPAQ-LF vs. HRM - Analysis 2*

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **HRM N=180** |
| Brisk Walking | 122.7 (81.3, 164.1) | 89.0 (66.6, 111.4) | 31.9 (19.3, 44.5) |
| Moderate | 271.5 (180.9, 362.1) | 313.7 (252.6, 374.8) | 114.6 (78.4, 150.8) |
| Vigorous | 211.0 (161.3, 260.7) | 158.6 (122.7, 194.5) | 93.3 (56.9, 129.7) |
| Total | 605.2 (487.7, 722.7) | 561.3 (478.2, 644.4) | 239.8 (188.1, 291.5) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with HRM, p-value** | | |
| Brisk Walking | 0.27, $p = 0.0003$ | 0.43, $p < 0.0001$ | -- |
| Moderate | 0.07, $p = 0.34$ | 0.02, $p = 0.81$ | -- |
| Vigorous | 0.27, $p = 0.0003$ | 0.35, $p < 0.0001$ | -- |
| Total | 0.25, $p = 0.0008$ | 0.25, $p = 0.0009$ | -- |
| **Activity Category** (total time over last 7 days) | **% in Activity Groups (n=180)** | | |
| Relatively Inactive: < 2.5 hours | 21.7 | 22.8 | 56.7 |
| Relatively Active: 2.5 to 5 hours | 21.7 | 19.4 | 17.8 |
| Highly Active: ≥ 5 hours | 56.7 | 57.8 | 25.6 |
| Weighted Kappa vs. HRM | 0.19 | 0.16 | -- |
| **Current NZ Guidelines**[6] | **% Meeting Current Recommendations (n=180)** | | |
| ≥ 30 min/day on ≥ 5 days | 34.4 | 42.2 | 5.6 |
| ≥ 150 min/week but < 5 days | 43.9 | 35.0 | 37.8 |
| Weighted Kappa vs. HRM | 0.12 | 0.12 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**Table 24.** NZPAQ-SF and NSPAQ-LF vs. HRM - Analysis 3*

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **HRM N=180** |
| Brisk Walking | 405.0 (268.4, 541.6) | 293.6 (219.7, 367.5) | 105.2 (63.7, 146.7) |
| Moderate | 1086.0 (723.6, 1448.4) | 1255.0 (1010.7, 1499.3) | 458.3 (313.6, 603.0) |
| Vigorous | 843.9 (645.0, 1042.8) | 634.5 (491.0, 778.0) | 373.3 (227.5, 519.1) |
| Total | 2335.0 (1874.0, 2796.0) | 2183.0 (1853.8, 2512.2) | 936.8 (732.3, 1141.3) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with HRM, p-value** | | |
| Brisk Walking | 0.27, p = 0.0003 | 0.43, p < 0.0001 | -- |
| Moderate | 0.07, p = 0.34 | 0.02, p = 0.81 | -- |
| Vigorous | 0.27, p =0.0003 | 0.35, p < 0.0001 | -- |
| Total | 0.26, p = 0.0005 | 0.25, p = 0.0008 | -- |
| **Activity Category†** (total time over last 7 days) | **% in Activity Categories (n=180)** | | |
| Insufficiently Active | 41.1 | 43.3 | 87.1 |
| Sufficiently Active | 23.9 | 25.6 | 3.9 |
| Highly Active | 35.0 | 31.1 | 9.4 |
| Weighted Kappa vs. HRM | 0.09 | 0.13 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**Table 25.** NZPAQ-SF and NZPAQ-LF vs. HRM - Analysis 4*

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **HRM N=180** |
| Brisk Walking | 583.5 (379.7, 787.3) | 413.2 (308.2, 518.2) | 144.4 (89.1, 199.7) |
| Moderate | 1595.0 (1051.0, 2139.0 | 1821.0 (1439.7, 2202.3) | 661.3 (448.7, 873.9) |
| Vigorous | 1238.0 (915.8, 1560.2) | 890.2 (681.1, 1099.3) | 464.3 (285.9, 642.7) |
| Total | 3417.0 (2682.0, 4152.0) | 3125.0 (2612.8, 3637.2) | 1269.0 (993.3, 1544.7) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with HRM, p-value** | | |
| Brisk Walking | 0.25, p = 0.0008 | 0.40, p < 0.0001 | -- |
| Moderate | 0.09, p = 0.21 | 0.01, p = 0.86 | -- |
| Vigorous | 0.26, p = 0.0005 | 0.33, p < 0.0001 | -- |
| Total | 0.25, p = 0.0008 | 0.22, p = 0.003 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups (n=180)** | | |
| < 1050 kcals/week | 31.2 | 28.5 | 65.1 |
| 1050-2099 kcals/week | 23.1 | 22.0 | 17.2 |
| ≥ 2100 kcals/week | 45.7 | 49.5 | 17.7 |
| Weighted Kappa vs. HRM | 0.18 | 0.13 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

**Table 26.** Comparison of Analyses 1-4*: Physical Activity Duration and Classification

| | **Mean Total Activity (95% CI)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Analysis 1 (min)** | | **Analysis 2 (min)** | | **Analysis 3 (MET-min)** | | **Analysis 4 (kcals)** | |
| HRM total activity | 193.1 (150.5, 235.7) | | 239.8 (188.1, 291.5) | | 936.8 (732.3, 1141.3) | | 1269 (993.3, 1544.7) | |
| NZPAQ-SF | 499.7 (392.8, 606.6) | | 605.2 (487.7, 722.7) | | 2335.0 (1874.0, 2796.0) | | 3417.0 (2682.0, 4152.0) | |
| Spearman's r, p-value | 0.18 p = 0.01 | | 0.25 p = 0.0008 | | 0.26 p = 0.0005 | | 0.25 p = 0.0008 | |
| NZPAQ-LF | 481.9 (409.7, 554.1) | | 561.3 (478.2, 644.4) | | 2183.0 (1853.8, 2512.2) | | 3125.0 (2612.8, 3637.2) | |
| Spearman's r, p-value | 0.19 p = 0.01 | | 0.25 p = 0.0009 | | 0.25 p = 0.0008 | | 0.22 p = 0.003 | |
| | **% in Activity Category (min)** | | | | **% in Activity Category† (MET-min)** | | **% in EE Category (kcals)** | |
| | **SF** | **LF** | **SF** | **LF** | **SF** | **LF** | **SF** | **LF** |
| < 2.5 hours or <1050kcals | 27.8 | 25.0 | 21.7 | 22.8 | 41.1 | 43.3 | 31.2 | 28.5 |
| 2.5 to 5 hours or 1050-2099 kcals | 21.7 | 21.1 | 21.7 | 19.4 | 23.9 | 25.6 | 23.1 | 22.0 |
| ≥ 5 hours or ≥ 2100 kcals | 50.6 | 53.9 | 56.7 | 57.8 | 35.0 | 31.1 | 45.7 | 49.5 |
| Wtd Kappa vs. HRM | 0.15 | 0.13 | 0.19 | 0.16 | 0.09 | 0.13 | 0.18 | 0.13 |
| ≥30min/day and ≥ 5days[24] | 35.0 | 19.9 | 35.5 | 21.5 | -- | -- | -- | -- |

*Analysis 1 - Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed. Analysis 2 - Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed. Analysis 3 - Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103, Analysis 4 - Total EE (kcals/week) calculated from equation on pg.103
SF = NZPAQ-SF, LF = NZPAQ=LF

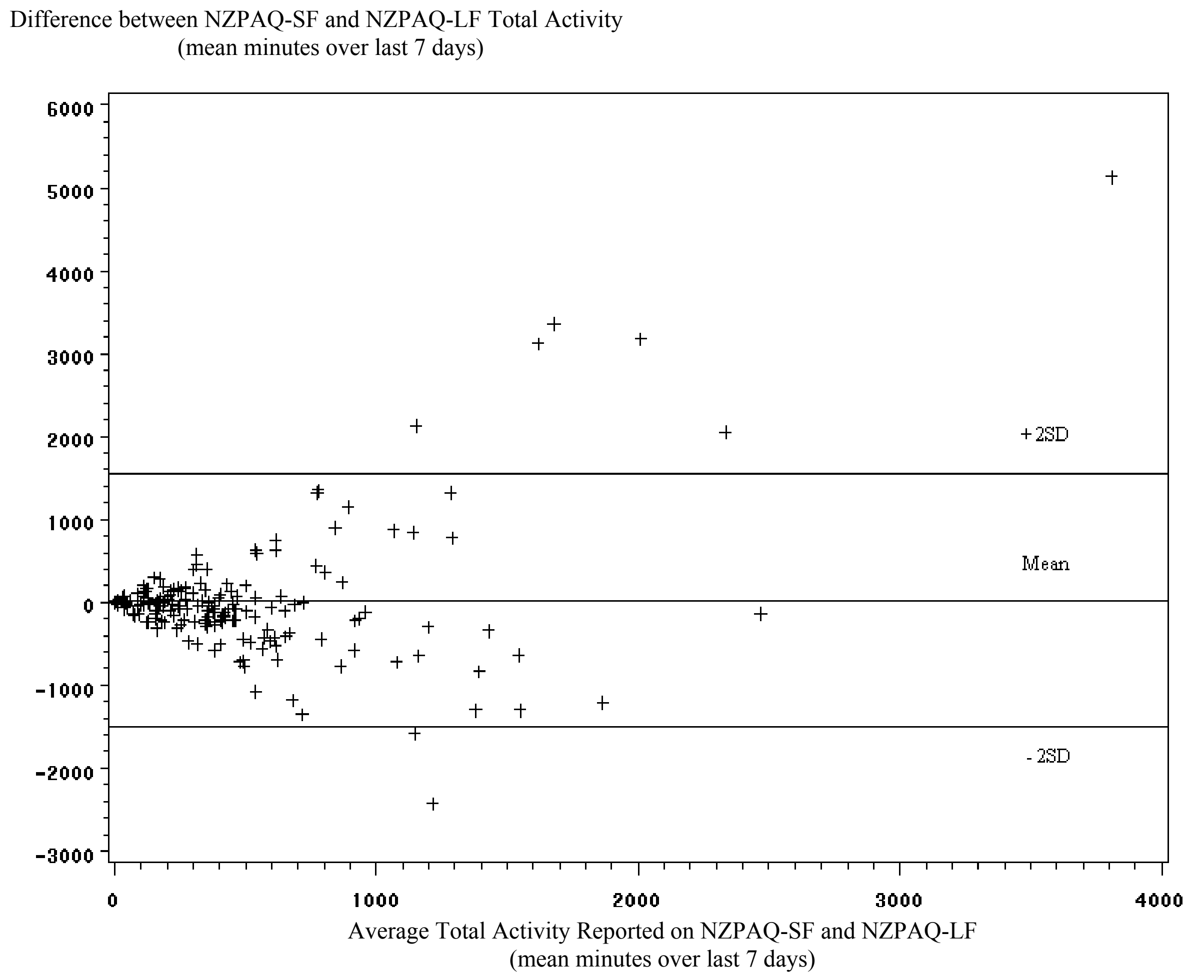
### 4.2.2 NZPAQ-SF vs. NZPAQ-LF

Average completion times for the NZPAQ-SF and NZPAQ-LF were 4 and 19 minutes, respectively. Table 27 shows the correlation between the NZPAQ-SF vs. NZPAQ-LF (Analysis 1). Brisk walking, moderate- and vigorous-intensity activity, and total activity over the last 7 days were all significantly correlated between the two questionnaires. Moderate correlation was observed between activity categories, and fair correlation between participants meeting the current guidelines. The Bland-Altman plot of activity reported on the NZPAQ-SF and NZPAQ-LF (Figure 5) illustrates better agreement between the questionnaires at lower PA levels. The magnitude of agreement diminishes as reported activity levels increase. Correlations between NZPAQ-SF and NZPAQ-LF by age, ethnicity and gender, by Analyses, 1, 2, 3, and 4, are located in Appendices B5-8 (pg.307), respectively.

**Table 27.** Correlation between NZPAQ-SF and NZPAQ-LF Physical Activity Components

| **Activity** | **NZPAQ-SF vs. NZPAQ-LF Spearman's r, p-value** |
|---|---|
| Brisk Walking | 0.61, p < 0.0001 |
| Moderate | 0.26, p = 0.0003 |
| Vigorous | 0.52, p < 0.0001 |
| Total | 0.48, p < 0.0001 |
| **Activity Category** (total time over last 7 days) | **Weighted Kappa** |
| Relatively Inactive: < 2.5 hours | 0.43 |
| Relatively Active: 2.5 to 5 hours | |
| Highly Active: ≥ 5 hours | |
| **Current NZ Guidelines**[6] | **Weighted Kappa** |
| ≥ 30 min/day on ≥ 5 days | 0.29 |
| ≥ 150 min/week but < 5 days | |

**Figure 5.** NZPAQ-SF vs. NZPAQ-LF: Agreement of Self-reported Duration of Physical Activity




### 4.2.3 NZPAQ-SF and NZPAQ-LF vs. NZSPAS

Table 28 shows the adjustment factor needed to convert data collected on the previous NZSPAS question, the NZPAQ-SF and NZPAQ-LF, pertaining to the duration of PAs during the last 7 days. The NZSPAS asked about total time spent in any intensity of sport and recreational PAs, which was recorded on the Main PA Table in the 'Total Time (L, M, V)' column (Appendix A, pg.251). NZPAQ-LF data was obtained from the last column on the Main PA Table. These results indicate that the NZSPAS underestimated sport/recreational PAs compared to the NZPAQs, and discrepancies were greatest for the middle-aged group (40-59 yrs) and Pacific people.

**Table 28.** Duration of Sport and Recreation Physical Activities: Adjustment Factors between NZPAQs and NZSPAS

| | | **Mean minutes over last 7 days (95% CI) by subgroup (Adjustment Factor)*** | | |
|---|---|---|---|---|
| | **n** | **NZPAQ-SF** | **NZPAQ-LF** | **NZSPAS** |
| Total Sample | 186 | 499.7 (392.8, 606.6) (1.47) | 481.9 (409.7, 554.1) (1.42) | 340.0 (278.7, 401.3) (1.0) |
| **Age Group** | | | | |
| 18-39 yrs | 64 | 377.4 (251.0, 503.8) (1.08) | 505.2 (384.4, 626.0) (1.44) | 350.5 (246.0, 455.0) (1.0) |
| 40-59 yrs | 60 | 506.6 (311.2, 702.0) (2.02) | 455.7 (331.9, 579.5) (1.81) | 251.2 (168.3, 334.1) (1.0) |
| 60+ yrs | 62 | 619.3 (397.5, 841.1) (1.49) | 483.4 (351.1, 615.7) (1.16) | 415.1 (291.4, 538.8) (1.0) |
| **Ethnicity** | | | | |
| European/Other | 60 | 514.0 (286.4, 741.6) (1.15) | 524.1 (414.3, 633.9) (1.18) | 445.6 (343.4, 547.8) (1.0) |
| Māori | 61 | 403.7 (276.8, 530.6) (1.14) | 500.1 (363.8, 636.4) (1.42) | 352.6 (231.5, 473.7) (1.0) |
| Pacific | 65 | 576.7 (388.8, 764.6) (2.50) | 426.0 (298.5, 553.5) (1.85) | 230.7 (141.3, 320.1) (1.0) |
| **Gender** | | | | |
| Male | 90 | 655.0 (469.1, 840.9) (1.60) | 589.9 (463.1, 716.7) (1.44) | 409.1 (304.6, 513.6) (1.0) |
| Female | 96 | 354.2 (249.6, 458.8) (1.29) | 380.7 (312.1, 449.3) (1.38) | 275.2 (210.0, 340.4) (1.0) |

* = ratio of NZPAQ-SF and NZPAQ-LF with NZSPAS

### 4.2.4 NZPAQ-SF and NZPAQ-LF vs. IPAQ-long

Tables 29, 30, 31, and 32 show results from the NZPAQ-SF and NZPAQ-LF vs. IPAQ-long comparison for analyses 1-4, respectively. Reported PA levels from the NZPAQ-SF and NZPAQ-LF compared to the IPAQ-long are illustrated by Bland-Altman plots in Figures 6 and 7, respectively.

Analyses 1-4 vs. IPAQ-long

Although the NZPAQ-SF and NZPAQ-LF showed significant moderate correlations to the IPAQ-long for brisk walking, moderate- and vigorous-intensity, and total activity, PA levels reported on the IPAQ-long were substantially greater. The NZPAQ-SF was more highly correlated to the IPAQ-long for brisk walking and vigorous-intensity activity, while the NZPAQ-LF was more highly correlated for moderate-intensity and total activity. The Bland-Altman plots illustrate that, as the difference in activity levels reported by IPAQ-long and both NZPAQ-SF (Figure 6) and NZPAQ-LF (Figure 7) increased, the limits of agreement became wider.

Physical Activity Categories

Activity categories had the highest agreement to the IPAQ-long using Analysis 2 methods (Table 30). All methods of analyses showed fair levels of agreement to IPAQ-long, which consistently reported considerably higher and lower proportions of participants in the 'highly active' and 'relatively inactive' categories.

**Table 29.** NZPAQ-SF and NZPAQ-LF vs. IPAQ-long - Analysis 1*

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **IPAQ-long N=186** |
| Brisk Walking | 122.7 (81.3, 164.1) | 89.0 (66.6, 111.4) | 283.6 (220.5, 346.7) |
| Moderate | 271.5 (180.9, 362.1) | 313.7 (252.6, 374.8) | 543.7 (450.2, 637.2) |
| Vigorous | 105.5 (80.6, 130.4) | 79.3 (61.4, 97.2) | 200.9 (149.3, 252.5) |
| Total | 499.7 (392.8, 606.6) | 481.9 (409.7, 554.1) | 1028.0 (884.7, 1171.3) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with IPAQ-long, p-value** | | |
| Brisk Walking | 0.37, p < 0.0001 | 0.32, p < 0.0001 | -- |
| Moderate | 0.23, p = 0.002 | 0.37, p < 0.0001 | -- |
| Vigorous | 0.49, p < 0.0001 | 0.43, p < 0.0001 | -- |
| Total | 0.33, p < 0.0001 | 0.43, p < 0.0001 | -- |
| **Activity Category** (total time over last 7 days) | **% in Activity Groups** | | |
| Relatively Inactive: < 2.5 hours | 26.9 | 24.2 | 10.2 |
| Relatively Active: 2.5 to 5 hours | 21.5 | 21.5 | 10.2 |
| Highly Active: ≥ 5 hours | 51.6 | 54.3 | 79.6 |
| Weighted Kappa vs. IPAQ | 0.25 | 0.28 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**Figure 6.** NZPAQ-SF vs. IPAQ-long: Agreement of Physical Activity Duration

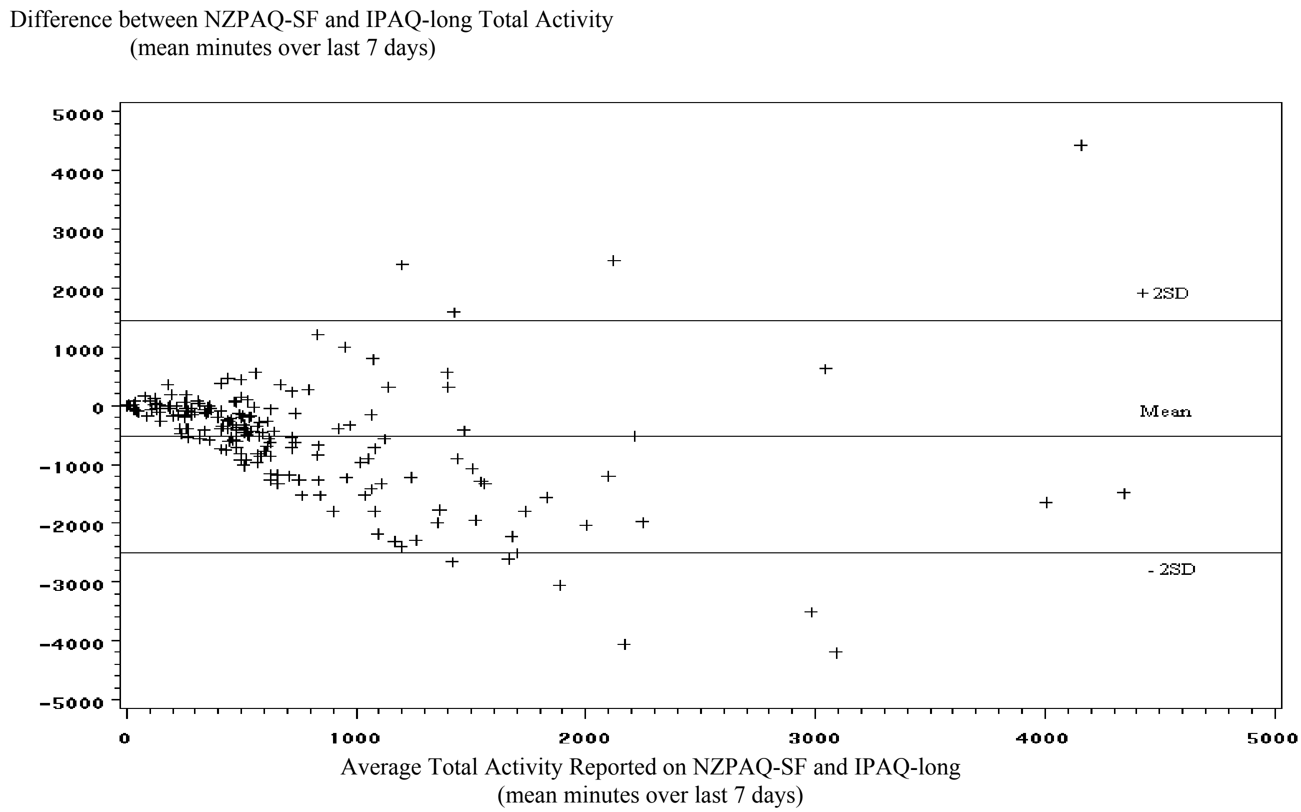



**Figure 7.** NZPAQ-LF vs. IPAQ-long: Agreement of Physical Activity Duration

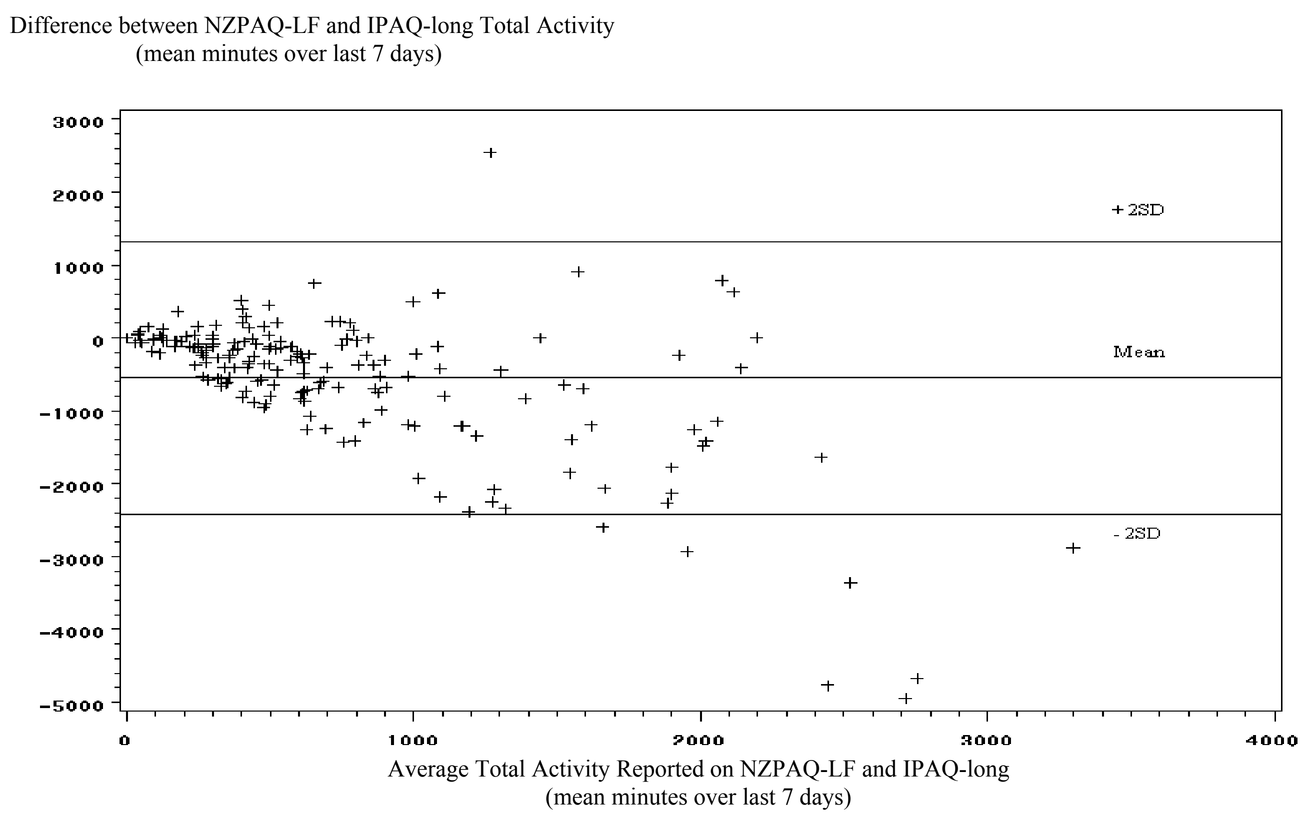


**Table 30.** NZPAQ-SF and NZPAQ-LF vs. IPAQ-long - Analysis 2*

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **IPAQ-long N=186** |
| Brisk Walking | 122.7 (81.3, 164.1) | 89.0 (66.6, 111.4) | 283.6 (220.5, 346.7) |
| Moderate | 271.5 (180.9, 362.1) | 313.7 (252.6, 374.8) | 543.7 (450.2, 637.2) |
| Vigorous | 211.0 (161.3, 260.7) | 158.6 (122.7, 194.5) | 401.8 (298.7, 504.9) |
| Total | 605.2 (487.7, 722.7) | 561.3 (478.2, 644.4) | 1229.0 (1049.1, 1408.9) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with IPAQ-long, p-value** | | |
| Brisk Walking | 0.37, p < 0.0001 | 0.32, p < 0.0001 | -- |
| Moderate | 0.23, p = 0.002 | 0.37, p < 0.0001 | -- |
| Vigorous | 0.49, p = < 0.0001 | 0.43, p < 0.0001 | -- |
| Total | 0.35, p < 0.0001 | 0.45, p < 0.0001 | -- |
| **Activity Category** (total time over last 7 days) | **% in Activity Groups** | | |
| Relatively Inactive: < 2.5 hours | 21.0 | 22.0 | 9.7 |
| Relatively Active: 2.5 to 5 hours | 21.5 | 19.4 | 7.5 |
| Highly Active: ≥ 5 hours | 57.5 | 58.6 | 82.8 |
| Weighted Kappa vs. IPAQ | 0.26 | 0.30 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**Table 31.** NZPAQ-SF and NZPAQ-LF vs. IPAQ-long - Analysis 3*

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **IPAQ-long N=186** |
| Brisk Walking | 405.0 (268.4, 541.6) | 293.6 (219.7, 367.5) | 935.8 (727.4, 1144.2) |
| Moderate | 1086.0 (723.6, 1448.4) | 1255.0 (1010.7, 1499.3) | 2175.0 (1801.2, 2548.8) |
| Vigorous | 843.9 (645.0, 1042.8) | 634.5 (491.0, 778.0) | 1607.0 (1194.5, 2019.5) |
| Total | 2335.0 (1874.0, 2796.0) | 2183.0 (1853.8, 2512.2) | 4718.0 (4023.3, 5412.7) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with IPAQ-long, p-value** | | |
| Brisk Walking | 0.37, p < 0.0001 | 0.32, p < 0.0001 | -- |
| Moderate | 0.23, p = 0.002 | 0.37, p < 0.0001 | -- |
| Vigorous | 0.49, p < 0.0001 | 0.43, p < 0.0001 | -- |
| Total | 0.35, p < 0.0001 | 0.46, p < 0.0001 | -- |
| **Activity Category†** (total time over last 7 days) | **% in Activity Groups** | | |
| Insufficiently Active | 39.8 | 41.9 | 14.5 |
| Sufficiently Active | 23.7 | 27.4 | 12.9 |
| Highly Active | 36.6 | 30.7 | 75.6 |
| Weighted Kappa vs. IPAQ | 0.22 | 0.20 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**Table 32.** NZPAQ-SF and NZPAQ-LF vs. IPAQ - Analysis 4*

| | **Mean activity energy expenditure (95% CI) in kcals/week over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=186** | **NZPAQ-LF N=186** | **IPAQ-long N=186** |
| Brisk Walking | 583.5 (379.7, 797.3) | 413.2 (308.2, 508.2) | 1370.0 (1045.9, 1694.1) |
| Moderate | 1595.0 (1051.0, 2139.0) | 1821.0 (1440.0, 2202.3) | 3078.0 (2527.3, 3628.7) |
| Vigorous | 1238.0 (915.8, 1560.2) | 890.2 (681.1, 1099.3) | 2392.0 (1716.1, 3067.9) |
| Total | 3417.0 (2682.0, 4152.0) | 3125.0 (2612.8, 3637.2) | 6840.0 (5728.8, 7951.2) |
| **Activity** | **Spearman's Correlation Coefficient (r) Compared with IPAQ-long, p-value** | | |
| Brisk Walking | 0.37, p < 0.0001 | 0.30, p < 0.0001 | -- |
| Moderate | 0.25, p = 0.0006 | 0.36, p < 0.0001 | -- |
| Vigorous | 0.51, p < 0.0001 | 0.44, p < 0.0001 | -- |
| Total | 0.35, p < 0.0001 | 0.46, p < 0.0001 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | |
| < 1050 kcals/week | 31.2 | 28.5 | 12.4 |
| 1050-2099 kcals/week | 23.1 | 22.0 | 11.3 |
| > 2100 kcals/week | 45.7 | 49.5 | 76.3 |
| Weighted Kappa vs. IPAQ | 0.21 | 0.26 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

### 4.2.5 IPAQ-long vs. HRM

Self-reported PA levels from the IPAQ-long compared to HRM data, by Analyses 1, 2, 3, and 4, are shown in Tables 33, 34, 35, and 36, respectively. PA levels reported on the IPAQ-long were consistently and substantially higher than HRM data for all PA components. Significant correlations existed between the IPAQ-long and HRM for brisk walking and vigorous-intensity PA, identified in all four analyses. The proportion of participants meeting current PA guidelines, captured by HRM and on the IPAQ-long, showed poor agreement, with weighted kappa (κ) values ranging from 0.02 (Analysis 1) to 0.06 (Analysis 2).

**Table 33.** IPAQ-long vs. HRM – Analysis 1*

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **IPAQ-long N=186** | **HRM N=180** | **Spearman's r, p-value** |
| Brisk Walking | 283.6 (220.5, 346.7) | 31.9 (19.3, 44.5) | 0.18, p = 0.02 |
| Moderate | 543.7 (450.2, 637.2) | 114.6 (78.4, 150.8) | 0.01, p = 0.92 |
| Vigorous | 200.9 (149.3, 252.5) | 46.7 (28.5, 64.9) | 0.25, p < 0.001 |
| Total | 1028.0 (884.7, 1171.3) | 193.1 (150.5, 235.7) | 0.02, p = 0.82 |
| **Activity Category** (total time over last 7 days) | **% in Activity Groups** | | **Weighted Kappa vs. HRM** |
| Relatively Inactive: < 2.5 hours | 10.2 | 58.9 | 0.02 |
| Relatively Active: 2.5 to 5 hours | 10.2 | 20.6 | |
| Highly Active: ≥ 5 hours | 79.6 | 20.6 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**Table 34.** IPAQ-long vs. HRM – Analysis 2*

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **IPAQ-long N=186** | **HRM N=180** | **Spearman's r. p-value** |
| Brisk Walking | 283.6 (220.5, 346.7) | 31.9 (19.3, 44.5) | 0.18, p = 0.02 |
| Moderate | 543.7 (450.2, 637.2) | 114.6 (78.4, 150.8) | 0.01, p = 0.92 |
| Vigorous | 401.8 (298.7, 504.9) | 93.3 (56.9, 129.7) | 0.25, p < 0.001 |
| Total | 1229.0 (1049.1, 1408.9) | 239.8 (188.1, 291.5) | 0.07, p = 0.37 |
| **Activity Category** (total time over last 7 days) | **% in Activity Groups** | | **Weighted Kappa vs. HRM** |
| Relatively Inactive: < 2.5 hours | 9.7 | 56.7 | 0.06 |
| Relatively Active: 2.5 to 5 hours | 7.5 | 17.8 | |
| Highly Active: ≥ 5 hours | 82.8 | 25.6 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**Table 35.** IPAQ-long vs. HRM – Analysis 3*

| | Mean MET-minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **IPAQ-long N=186** | **HRM N=180** | **Spearman's r. p-value** |
| Brisk Walking | 935.8 (727.4, 1144.2) | 105.2 (63.7, 146.7) | 0.18, p = 0.02 |
| Moderate | 2175.0 (1801.2, 2548.8) | 458.3 (313.6, 603.0) | 0.01, p = 0.92 |
| Vigorous | 1607.0 (1194.5, 2019.5) | 373.3 (227.5, 519.1) | 0.25, p < 0.001 |
| Total | 4718.0 (4023.3, 5412.7) | 936.8 (732.3, 1141.3) | 0.08, p = 0.31 |
| **Activity Category** (total time over last 7 days) | **% in Activity Groups** | | **Weighted Kappa vs. HRM** |
| Relatively Inactive: < 2.5 hours | 14.5 | 87.1 | 0.05 |
| Relatively Active: 2.5 to 5 hours | 12.9 | 3.9 | |
| Highly Active: ≥ 5 hours | 75.6 | 9.4 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**Table 36.** IPAQ-long vs. HRM – Analysis 4*

| | **Mean activity energy expenditure (95% CI) in kcals/week over last 7 days** | | |
|---|---|---|---|
| **Activity** | **IPAQ-long N=186** | **HRM N=180** | **Spearman's r. p-value** |
| Brisk Walking | 1370.0 (1045.9, 1694.1) | 144.4 (89.1, 199.7) | 0.15, p = 0.04 |
| Moderate | 3078.0 (2527.3, 3628.7) | 661.3 (448.7, 873.9) | 0.02, p = 0.78 |
| Vigorous | 2392.0 (1716.1, 3067.9) | 464.3 (285.9, 642.7) | 0.23, p = 0.002 |
| Total | 6840.0 (5728.8, 7951.2) | 1269.0 (993.3, 1544.7) | 0.07, p = 0.36 |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | **Weighted Kappa vs. HRM** |
| < 1050 kcals/week | 12.4 | 65.1 | 0.03 |
| 1050-2099 kcals/week | 11.3 | 17.2 | |
| > 2100 kcals/week | 76.3 | 17.7 | |

*Total EE (kcals/week) calculated from equation on pg.103

## 4.3 PARTICIPANT RECALL – PHYSICAL ACTIVITY MODE AND DURATION

Self-report instruments rely heavily on participants' ability to accurately recall historical PA, a highly complex, cognitive task.[42,165] Identifying the recall accuracy of PA dimensions is an important aspect for refinement of PAQs, as this information assists PA researchers in modifying the measurement instrument to better suit the intended respondents and ensure the instrument captures the appropriate data. There is currently a limited understanding of the recall process, which deserves more attention.[23,165]

In this study, participants' ability to recall the type and duration of PA performed during the 3-day HRM period was evaluated. The 3-day HRM period captured activity bouts of at least moderate-intensity performed for a minimum of 10 minutes. All activities performed during HRM (and perceived as at least moderate-intensity) were documented by participants on PA Logs, and the researchers recorded corresponding duration and intensity of each activity from HRM data. The Main PA Table in the NZPAQ-LF, which was completed 3-4 days following HRM, required participants to recall activity mode, duration and intensity for the last 7 days. The 3 days of recalled PA were compared to PA Logs to assess participants' recall ability.

### 4.3.1 Recall of Physical Activity Duration

Total duration of PA captured during HRM and recalled on the NZPAQ-LF was moderately and significantly correlated ($r=0.30$, $p<0.0001$) (Table 37). However, participants' recalled duration of moderate-intensity PAs was 3 times higher than duration measured by HRM. Compared to moderate-intensity PA, a substantially stronger correlation and lower mean difference was found for vigorous-intensity activity ($r=0.34$, $p<0.001$), and this finding is consistent throughout every ethnic, age, and gender subgroup (Tables 38-45). These data lend strong support to the notion that higher intensity activities are more easily recalled.[50]

**Table 37.** Actual vs. Recalled Duration of Physical Activity: Total Sample (N = 186)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 76.3 (52.0, 100.6)<br>SE = 12.4 | 211.9 (164.4, 259.4)<br>SE = 24.2 | 135.7 | r = 0.30<br>p < 0.0001 |
| Moderate-Intensity | 57.4 (34.4, 80.4)<br>SE = 11.7 | 172.0 (129.0, 215.0)<br>SE = 22.0 | 114.6 | r = 0.12<br>p = 0.09 |
| Vigorous-Intensity | 18.9 (8.8, 29.1)<br>SE = 5.2 | 40.0 (27.9, 52.1)<br>SE = 6.2 | 21.1 | r = 0.34<br>p < 0.0001 |

Subgroup Data

Recall data for European/Other, Māori and Pacific participants are presented in Tables 38, 39, and 40, respectively. The European/Other sample demonstrates the most accurate recall ability of duration in total activity (r=0.57, p<0.0001), moderate- (r=0.36, p<0.01) and vigorous-intensity activities (r=0.42, p=0.0008). Estimates of total, moderate- and vigorous-intensity activity were over-reported on the NZPAQ-LF by all ethnic groups, with the greatest discrepancy observed for Māori participants' recall of moderate-intensity activity (Table 39).

**Table 38.** Actual vs. Recalled Duration of Physical Activity: European/Other (n=60)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 124.6 (96.1, 153.1)<br>SE = 14.5 | 246.7 (196.3, 297.1)<br>SE = 25.7 | 122.1 | r = 0.57<br>p < 0.0001 |
| Moderate-Intensity | 87.3 (58.9, 115.7)<br>SE = 14.5 | 186.2 (138.9, 233.5)<br>SE = 24.1 | 98.9 | r = 0.36<br>p < 0.01 |
| Vigorous-Intensity | 37.3 (23.1, 51.5)<br>SE = 7.3 | 60.5 (46.2, 74.8)<br>SE = 7.3 | 23.2 | r = 0.42<br>p < 0.001 |

**Table 39.** Actual vs. Recalled Duration of Physical Activity: Māori (n=61)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 76.5 (49.1, 103.9)<br>SE = 14.0 | 239.1 (186.4, 291.8)<br>SE = 26.9 | 162.7 | r = 0.09<br>p = 0.50 |
| Moderate-Intensity | 62.5 (36.3, 88.7)<br>SE = 13.4 | 203.0 (155.5, 250.5)<br>SE = 24.2 | 140.4 | r = -0.11<br>p = 0.39 |
| Vigorous-Intensity | 13.9 (5.5, 22.3)<br>SE = 4.3 | 36.2 (25.5, 46.9)<br>SE = 5.5 | 22.2 | r = 0.22<br>p = 0.08 |

**Table 40.** Actual vs. Recalled Duration of Physical Activity: Pacific (n=65)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 31.4 (22.2, 40.6)<br>SE = 4.7 | 154.3 (117.4, 191.2)<br>SE = 18.8 | 122.9 | r = 0.19<br>p = 0.13 |
| Moderate-Intensity | 24.9 (16.9, 32.9)<br>SE = 4.1 | 129.7 (97.1, 162.3)<br>SE = 16.6 | 104.8 | r = 0.12<br>p = 0.36 |
| Vigorous-Intensity | 6.5 (0.9, 12.1)<br>SE = 2.8 | 24.6 (14.6, 34.6)<br>SE = 5.1 | 18.1 | r = 0.20<br>p = 0.12 |

Tables 41, 42, and 43 present recall data for 18-39 yrs, 40-59 yrs, and 60+ yrs age groups, respectively. Moderate, significant correlations are noted in total activity duration reported by the two younger age groups, while measured and reported moderate-intensity PA was poorly recalled by all age groups. However, recall for time spent in vigorous-intensity activity was much stronger and nearly identical among the different age groups.

**Table 41.** Actual vs. Recalled Duration of Physical Activity: 18-39 yrs (n=64)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 71.0 (50.2, 91.8)<br>SE = 10.6 | 230.5 (181.2, 279.8)<br>SE = 25.1 | 159.5 | r = 0.36<br>p < 0.01 |
| Moderate-Intensity | 45.6 (25.6, 65.6)<br>SE = 10.2 | 172.3 (130.9, 213.7)<br>SE = 21.1 | 126.6 | r = 0.11<br>p = 0.39 |
| Vigorous-Intensity | 25.3 (15.7, 34.9)<br>SE = 4.9 | 58.2 (43.5, 72.9)<br>SE = 7.5 | 32.9 | r = 0.30<br>p = 0.02 |

**Table 42.** Actual vs. Recalled Duration of Physical Activity: 40-59 yrs (n=60)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 91.3 (62.4, 120.2)<br>SE = 14.7 | 198.7 (147.6, 249.8)<br>SE = 26.1 | 107.4 | r = 0.34<br>p < 0.01 |
| Moderate-Intensity | 72.2 (45.4, 99.0)<br>SE = 13.7 | 164.0 (114.0, 214.0)<br>SE = 25.5 | 91.8 | r = 0.18<br>p = 0.18 |
| Vigorous-Intensity | 19.2 (7.5, 30.9)<br>SE = 6.0 | 34.7 (24.9, 44.5)<br>SE = 5.0 | 15.6 | r = 0.30<br>p = 0.02 |

**Table 43.** Actual vs. Recalled Duration of Physical Activity: 60+ yrs (n=62)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 67.2 (44.3, 90.1)<br>SE = 11.7 | 205.6 (163.4, 247.8)<br>SE = 21.5 | 138.4 | r = 0.14<br>p = 0.26 |
| Moderate-Intensity | 55.2 (33.3, 77.1)<br>SE = 11.2 | 179.3 (141.6, 217.0)<br>SE = 19.2 | 124.1 | r = 0.08<br>p = 0.52 |
| Vigorous-Intensity | 12.0 (2.7, 21.3)<br>SE = 4.8 | 26.3 (16.0, 36.6)<br>SE = 5.3 | 14.3 | r = 0.29<br>p = 0.02 |

Recall of PA duration by males (Table 44) and females (Table 45) showed moderate, significant correlations for time spent in total activity, whereas duration of moderate-intensity activity was poorly recalled. Male participants demonstrated more accurate recall of time spent in vigorous-intensity activity ($r=0.35$, $p<0.001$) compared to females ($r=0.22$, $p=0.03$).

**Table 44.** Actual vs. Recalled Duration of Physical Activity: Males (n=90)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 92.6 (65.4, 119.8)<br>SE = 13.9 | 262.2 (204.3, 320.1)<br>SE = 29.5 | 169.7 | r = 0.28<br>p < 0.01 |
| Moderate-Intensity | 64.2 (38.5, 89.9)<br>SE = 13.1 | 209.5 (157.1, 261.9)<br>SE = 26.7 | 145.3 | r = 0.08<br>p = 0.45 |
| Vigorous-Intensity | 28.4 (16.2, 40.6)<br>SE = 6.2 | 52.7 (38.2, 67.2)<br>SE = 7.4 | 24.3 | r = 0.35<br>p < 0.001 |

**Table 45.** Actual vs. Recalled Duration of Physical Activity: Females (n=96)

| Mean minutes (95% CI) | | | | |
|---|---|---|---|---|
| | **HRM** | **NZPAQ-LF** | **Mean Difference** | **Spearman's correlation (r), p-value** |
| Total Activity | 61.0 (40.1, 81.9)<br>SE = 10.7 | 164.8 (132.2, 197.4)<br>SE = 16.6 | 103.8 | r = 0.30<br>p < 0.01 |
| Moderate-Intensity | 51.0 (30.8, 71.1)<br>SE = 10.3 | 136.8 (106.3, 167.3)<br>SE = 15.6 | 85.7 | r = 0.19<br>p = 0.06 |
| Vigorous-Intensity | 10.0 (2.4, 17.6)<br>SE = 3.9 | 28.0 (19.3, 36.7)<br>SE = 4.4 | 18.0 | r = 0.22<br>p = 0.03 |

The correlations between total, moderate-, and vigorous-intensity PA duration captured during HRM and duration of PA reported on the NZPAQ-LF, are illustrated in Figures 8, 9, and 10, respectively. The majority of participants who engaged in high levels of PA (~100+ min/day) had a tendency to under-report duration of activities. HR data for many participants who reported moderate- (Figure 9) and vigorous-intensity (Figure 10) PA during the 3-day HRM period showed '0' minutes of activity (depicted by data points along the y-axis), signifying a general inability to distinguish between physiological differences associated with light- and moderate-, and vigorous-intensity PAs. Recall for duration of moderate-intensity PA was more accurate from participants who performed such activity for 14+ min/day (x=3.6) (Figure 9). Participants who performed 18+ min/day of vigorous-intensity PA (x=4) displayed better recall of this activity, compared to less vigorously-active participants (Figure 10).

**Figure 8.** NZPAQ-LF vs. HRM: 3-day Total Activity Duration

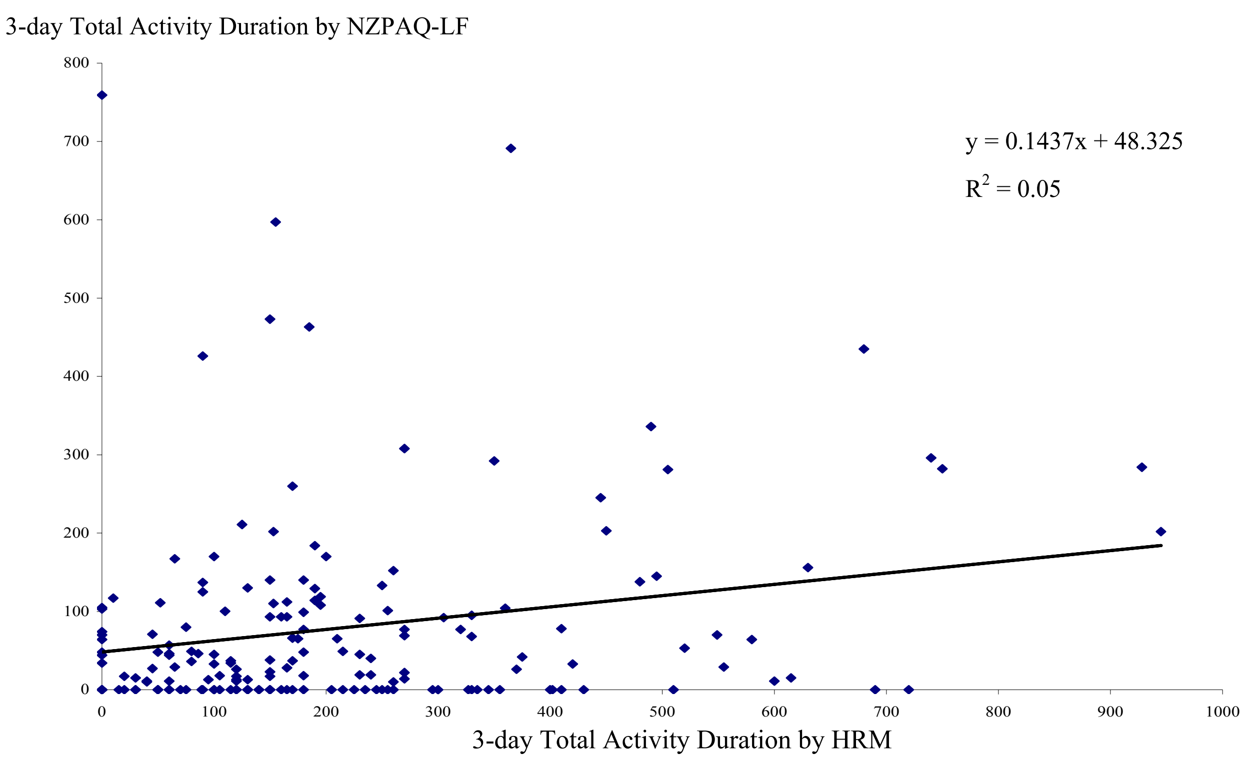


**Figure 9.** NZPAQ-LF vs. HRM: 3-day Moderate-Intensity Activity Duration

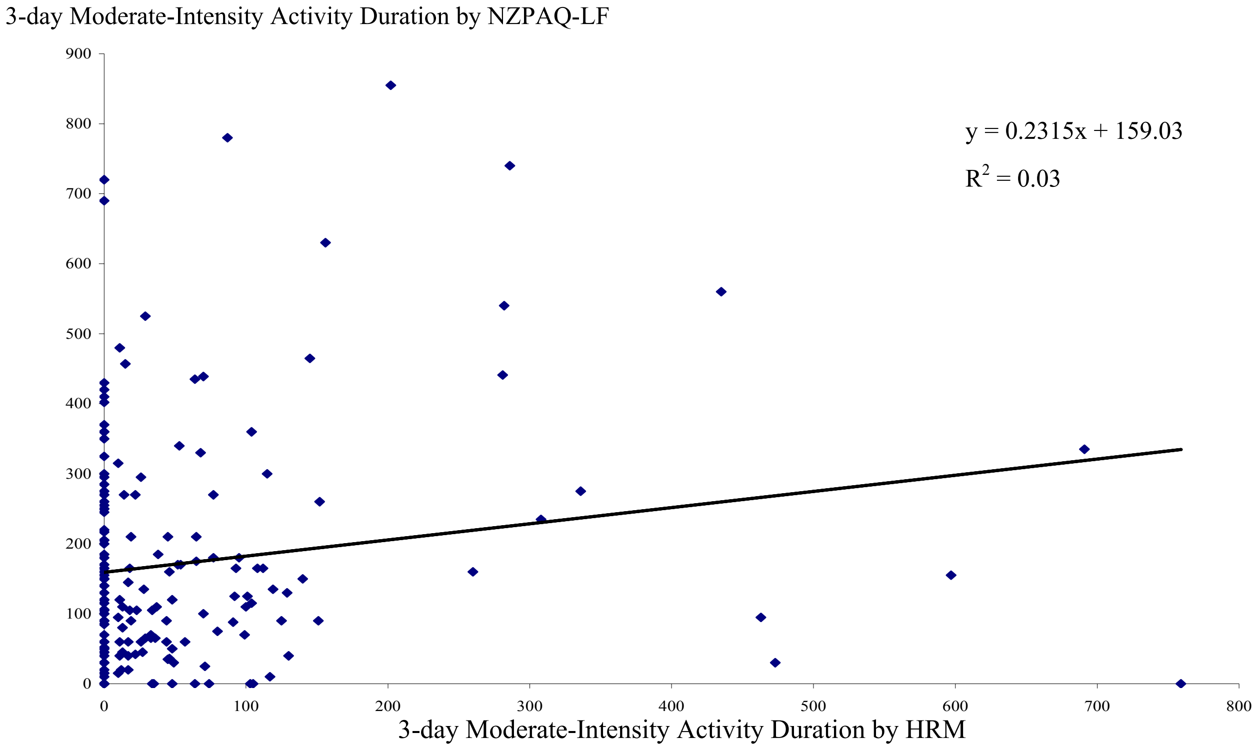
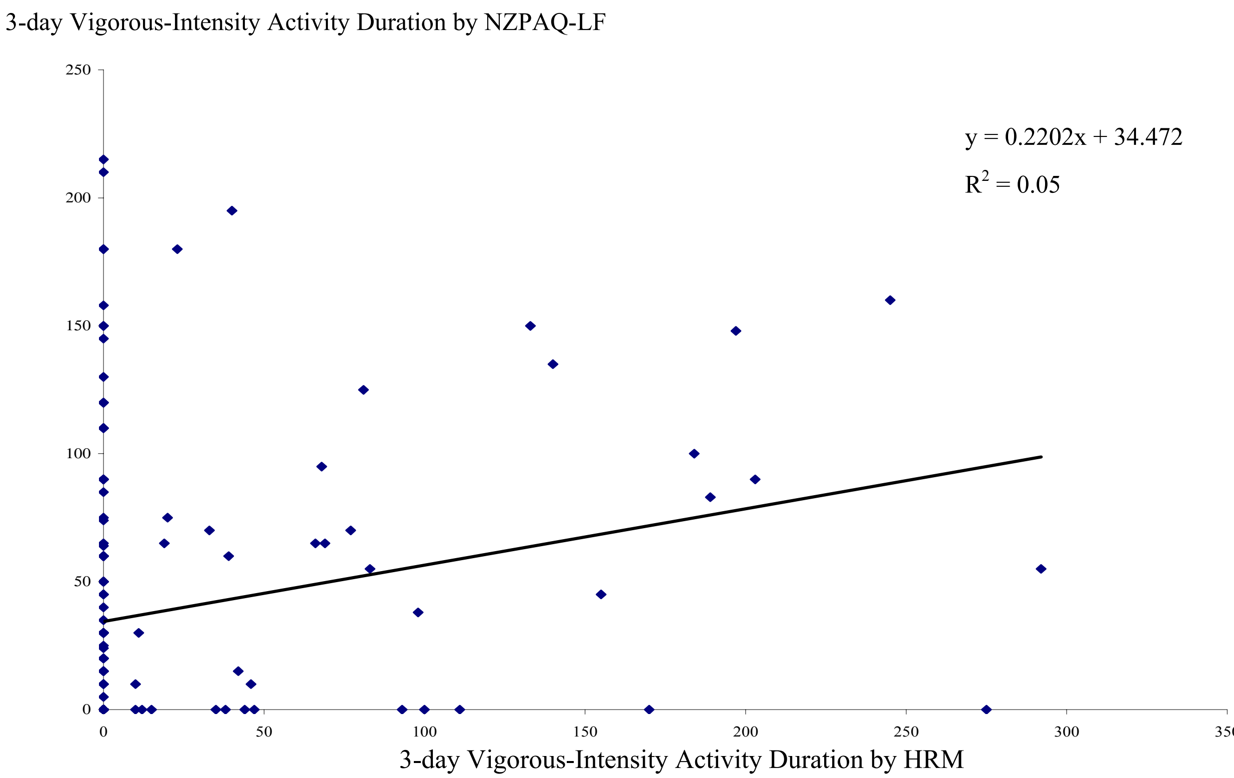



**Figure 10.** NZPAQ-LF vs. HRM: 3-day Vigorous-Intensity Activity Duration



Bland-Altman plots, which show agreement between self-reported and HRM-derived durations of total, moderate-, and vigorous-intensity PA, are shown in Figures 11, 12, and 13, respectively. Bland-Altman plots are ideal for illustrating the relationship between two variables of normal distribution, as they make no assumptions. However, the duration data were not normally distributed, and required conversion to their equivalent natural log (ln) values prior to calculating the difference between self-reported and HRM-derived PA duration, represented along the y-axes (NZPAQ values – HRM values). A large number of participants had 0 minutes of PA captured during HRM, which produced errors when converting data to natural logarithmic values, so 0.5 minutes was added to the duration data prior to the conversions. The ln of ‘0’ is -0.7, so the data points associated with x=-0.7 represent duration data for participants with ‘0’ minutes of activity during HRM. Each figure shows a small proportion of outlying data points forming a negatively-sloped straight line below the x-axis, which represent participants who performed PA during HRM, but reported 0 minutes of PA on the NZPAQ-LF. This line of data points results from subtracting ln values of HRM data from -0.7, the ln value equivalent to 0 minutes of activity reported on the NZPAQ-LF. For these participants, their absolute value on the y-axis is approximately equal to their value on the x-axis, but with a negative sign, hence the line of data sloping downward to the right.

**Figure 11.** NZPAQ-LF vs. HRM: Agreement of 3-day Total Activity Duration

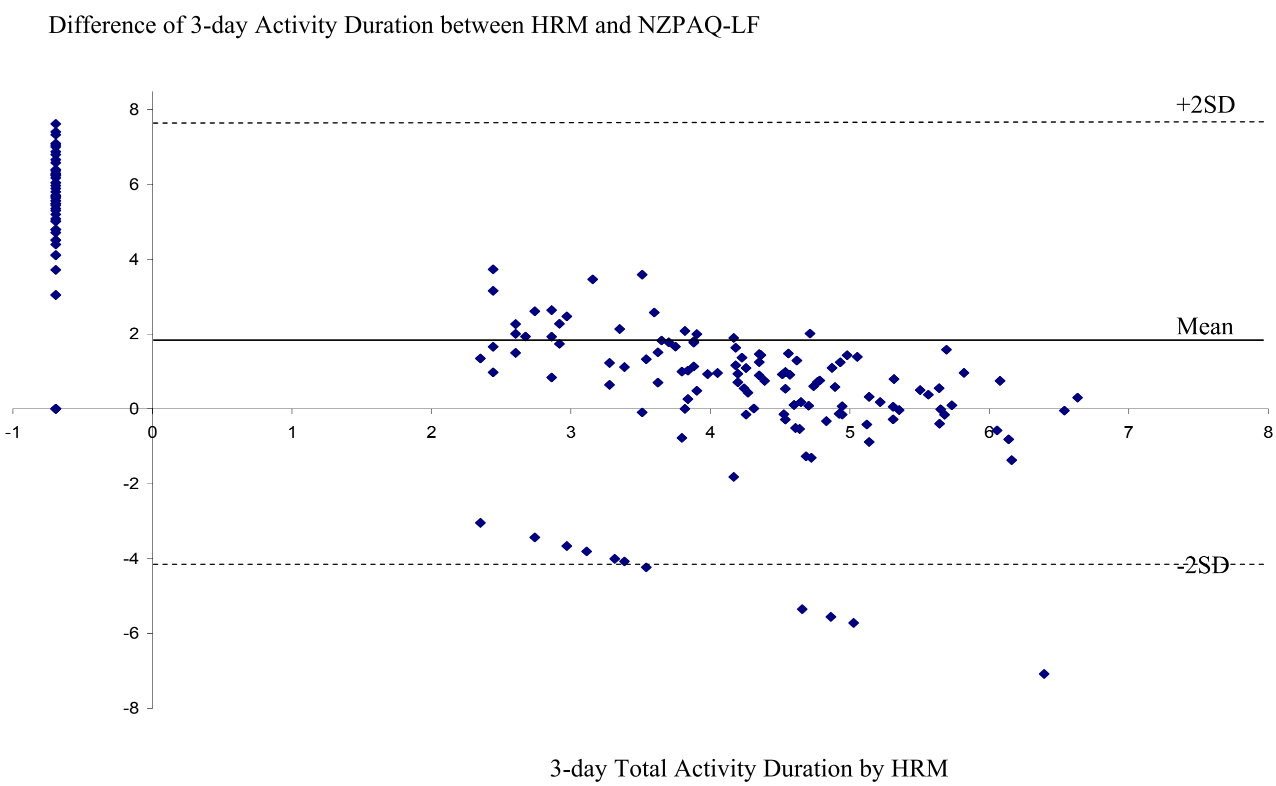


**Figure 12.** NZPAQ-LF vs. HRM: Agreement of Duration in Moderate-Intensity Physical Activities

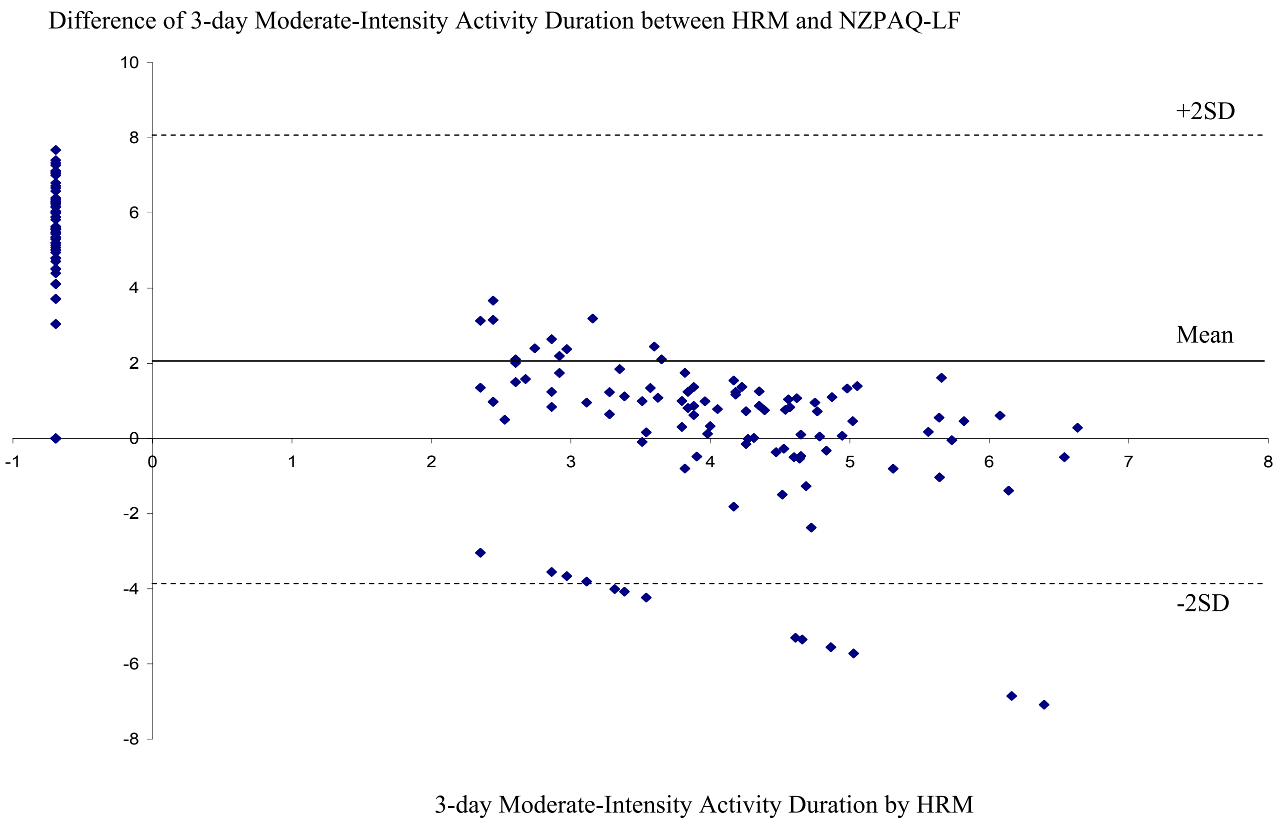
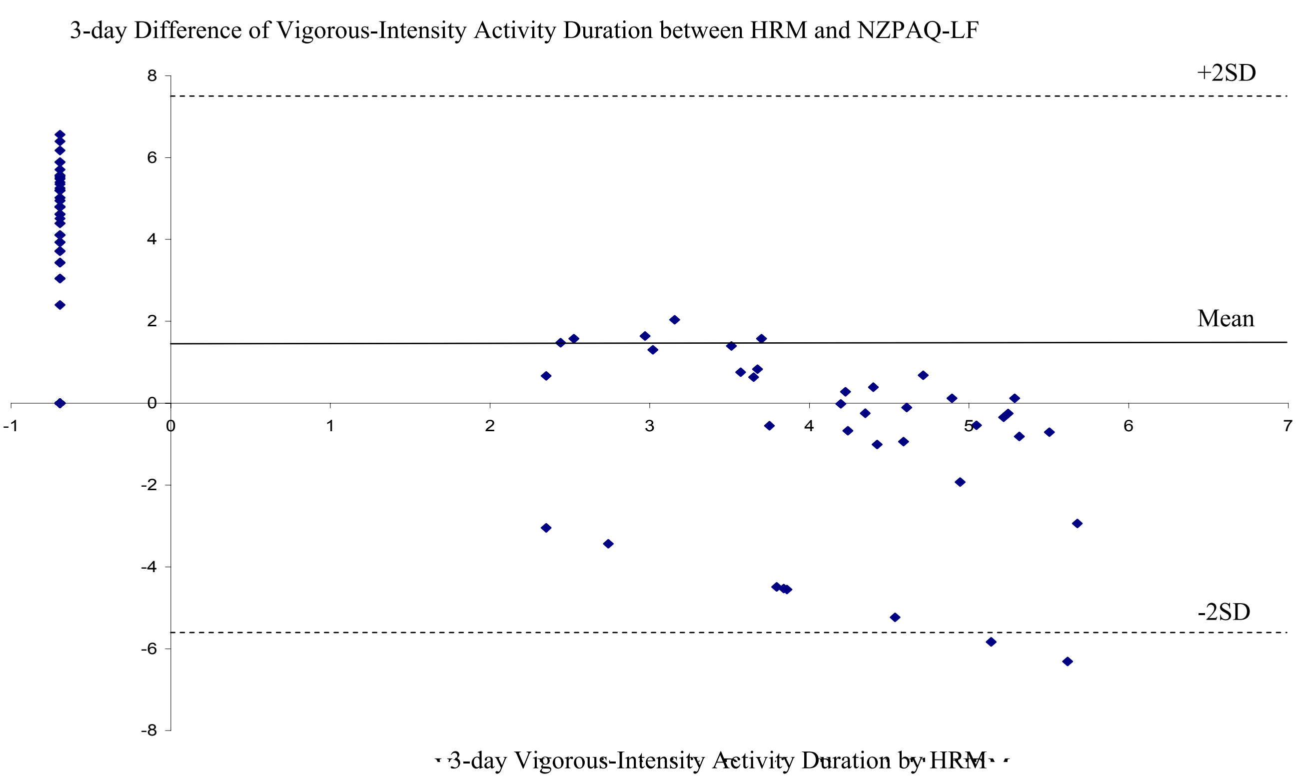



**Figure 13.** NZPAQ-LF vs. HRM: Agreement of Duration in Vigorous-Intensity Physical Activities



### 4.3.2 Recall of Physical Activity Mode

The PA Logs allowed participants to report any activity they engaged in which elicited a HR of at least moderate-intensity for a minimum of 10 minutes. The NZPAQ-LF, which was administered 3-4 days after HRM, required participants to recall their participation in all contexts of PA over the last 7 days. Approximately 14% of activity episodes captured during HRM were coded as 'Unknown' activity, where participants were unable to report an activity mode for the elevated HR response. The tallied counts of the numbers of activities reported on PA Logs and the NZPAQ-LF are presented in Appendix C, pg.327.

Sensitivity of the PA Logs was calculated (from equation in Section 3.6.1) to determine the proportion of PAs which were accurately recalled on the NZPAQ-LF. Data recorded on PA Logs and recalled on the NZPAQ-LF showed 332 PAs were accurately recalled, while 100 PAs were recorded on PA Logs, but not recalled on the NZPAQ-LF. The calculation revealed a sensitivity level of 76.9% for the PA Logs. Further analyses were carried out for separate PA contexts, as well as Māori activities, and are shown in Table 46. Activities most and least accurately recalled are listed in Table 47. The poorest recall of PA context was reported for Incidental/Other PA.

**Table 46.** Recall of Activity Mode by Physical Activity Context: PA Logs vs. NZPAQ-LF

| Physical Activity Context | Spearman's Correlation Coefficient (r) | $R^2$ |
|---|---|---|
| All Activity | 0.76 | 0.58 |
| Sports/Recreation | 0.92 | 0.85 |
| Māori Activities | 0.98 | 0.96 |
| Transport | 0.99 | 0.99 |
| Occupation | 0.72 | 0.51 |
| Incidental/Other | 0.64 | 0.41 |

**Table 47.** Accurately and Poorly Recalled Physical Activity Modes

| **Accurately Recalled* Activities** | **Poorly Recalled* Activities** |
|---|---|
| Aerobics | Exercising at home |
| Basketball | Gardening |
| Bowls – outdoor/lawn | Running/Jogging/Cross-country |
| Bowls – indoor | Walking for enjoyment or exercise (10-30 min) |
| Exercise classes/Going to the gym | Walking for enjoyment or exercise (> 30 min) |
| Golf | Kapahaka |
| Horse riding/Equestrian | Martial Arts/Dancing |
| Rugby - union | Transport – Walking |
| Soccer | Occupation – Carrying light loads |
| Swimming | Incidental – General cleaning |
| Tennis | Incidental - Walking - light, non-cleaning (ready to leave, shut/lock doors, close windows) |
| Volleyball | Incidental – Self care |
| Other (Trampoline, Petanque) | Incidental - Multiple household activities (moderate) |
| Occupation - Moving/lifting/carrying heavy loads | Incidental - Childcare |
| Occupation - Light/moderate cleaning | Kitchen activity - cooking, washing dishes |
| Incidental – Lawn mowing | Other (un/packing, non-church singing, shopping, playing instrument, laundry, auto repair, board games, caring for animals, take out rubbish) |
| Incidental – Home repair | |

*Refer to Appendix C for specific counts from PA Log and NZPAQ-LF

## 4.4 CREATION OF A NEW ZEALAND COMPENDIUM OF PHYSICAL ACTIVITES

PA intensities performed by different cultures or populations may differ significantly. Metabolic equivalents (METs) associated with PAs reported and analysed in this study were compared to MET values published in the Compendium of Physical Activities created in the United States (US),[24] an internationally-accepted instrument used to classify PAs by EE rates. In an effort to facilitate comparisons, Tables 48-55 categorise PAs captured in this study into major headings found in the US Compendium (Sport and Recreation, Ball Games, Water Activities, Transportation, Occupation, Other/Incidental, Home, Lawn and Garden Activities). Activities captured during HRM at least 10 times were further analysed by age and gender. Some participants engaged in PAs not included in the US Compendium, and associated MET levels serve as baseline data for population-specific PAs in NZ.

### 4.4.1 Sport and Recreation Physical Activities

Mean MET levels for PAs performed in the context of sport and recreation, ball games, and water activities are listed in Tables 48, 49 and 50, respectively. The majority of sport and recreation PAs yielded similar MET levels to the US Compendium, although some showed differences. Discrepancies were large enough for the following four PAs to classify them into different intensity categories:

- Martial Arts/Dancing: 2.7 METs in current study vs. 6.3 METs in US Compendium
- Rowing: 4.8 METs in current study vs. 7.0 METs in US Compendium
- Tennis: 5.8 METs in current study vs. 7.0 METs in US Compendium
- Trampoline: 6.1 METs in current study vs. 3.5 METs in US Compendium

MET levels for the following PAs were closely matched with the US Compendium:

- Aerobics
- Basketball
- Bowling - outdoor/lawn
- Exercising at home
- Running/Jogging/Cross-country
- Soccer
- Swimming (general)
- Volleyball
- Walking for enjoyment or exercise (>30 min)

Two PAs captured during HRM which were not listed in the US Compendium were:

- Petanque: 4.4 METs (moderate)
- Touch rugby: 6.4 METs (vigorous)

Subgroup Analyses

Subgroup analyses were performed on seven sport and recreation PAs. Females and participants aged 60+ yrs performed four and five PAs at lower mean MET levels, respectively, compared to males and younger participants. Consequently, three PAs were classified into lighter intensity categories when performed by females or participants aged 60+ years: aerobics, exercise classes/going to the gym/weight training, and swimming.

**Table 48.** NZ vs. US Mean METs for Sport and Recreation Activities

| NZPAQ CODE | SPORT/RECREATION ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 1 | Aerobics | 12 | 6.6 (6.3, 6.9) | 03015 | 6.5 |
| | 18-39 yrs | 10 | 7.0 (6.7, 7.3) | -- | -- |
| | 40-59 yrs | 1 | 5.3 | -- | -- |
| | 60+ yrs | 1 | 3.5 | -- | -- |
| | Male | 6 | 7.4 (7.2, 7.6) | -- | -- |
| | Female | 6 | 5.7 (5.4, 6.0) | -- | -- |
| 10 | Cycling - competitive | 3 | 10.0 (9.6, 10.4) | 01050 | 12.0 |
| 11 | Cycling - recreational (not mountain biking) | 1 | 8.7 | 01015 | 8.0 |
| 12 | Exercise classes/Going to the gym (other than aerobics work)/Weight training | 26 | 5.0 (4.6, 5.4) | 02060<br>02130<br>02050 | Gym exercise 5.5<br>Weights (lt) 3.0,<br>Weights (vig) 6.0 |
| | 18-39 yrs | 7 | 5.3 (5.2, 5.4) | -- | -- |
| | 40-59 yrs | 12 | 6.2 (5.9, 6.5) | -- | -- |
| | 60+ yrs | 7 | 2.5 (2.4, 2.6) | -- | -- |
| | Male | 16 | 5.9 (5.7, 6.1) | -- | -- |
| | Female | 10 | 4.4 (4.0, 4.8) | -- | -- |

| NZPAQ CODE | SPORT/RECREATION ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 13 | Exercising at home | 11 | 3.8 (3.7, 3.9) | 02030 | 3.5 |
| | 18-39 yrs | 2 | 3.9 (3.9, 3.9) | -- | -- |
| | 40-59 yrs | 5 | 3.4 (3.4, 3.4) | -- | -- |
| | 60+ yrs | 4 | 4.1 (4.0, 4.2) | -- | -- |
| | Male | 2 | 4.6 (4.5, 4.7) | -- | -- |
| | Female | 9 | 3.6 (3.6, 3.6) | -- | -- |
| 22 | Rowing | 2 | 4.8 (4.6, 5.0) | 02070 | 7.0 |
| 26 | Running/Jogging/Cross-country | 21 | 7.4 (7.0, 7.8) | 12150<br>12020<br>12140 | General running 8.0<br>General jogging 7.0<br>Cross-country 9.0 |
| | 18-39 yrs | 15 | 7.5 (7.0, 8.0) | -- | -- |
| | 40-59 yrs | 4 | 7.1 (7.0, 7.4) | -- | -- |
| | 60+ yrs | 2 | 6.9 (6.2, 7.6) | -- | -- |
| | Male | 12 | 7.1 (6.7, 7.5) | -- | -- |
| | Female | 9 | 7.7 (7.2, 8.2) | -- | -- |
| 40 | Walking for enjoyment or exercise (10-30min) | 47 | 4.4 (4.2, 4.6) | 17160<br>17250 | Pleasure 3.5<br>Exercise 3.8 |
| | 18-39 yrs | 27 | 4.4 (4.1, 4.7) | -- | -- |
| | 40-59 yrs | 6 | 4.2 (4.1, 4.3) | -- | -- |
| | 60+ yrs | 14 | 4.4 (4.1, 4.7) | -- | -- |
| | Male | 15 | 4.4 (4.1, 4.7) | -- | -- |
| | Female | 32 | 4.4 (4.2, 4.6) | -- | -- |

| NZPAQ CODE | SPORT/RECREATION ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 41 | Walking for enjoyment or exercise (>30min) | 33 | 3.7 (3.4, 4.0) | 17160 17250 | Pleasure 3.5 Exercise 3.8 |
| | 18-39 yrs | 7 | 4.7 (4.5, 4.9) | -- | -- |
| | 40-59 yrs | 7 | 3.9 (3.6, 4.2) | -- | -- |
| | 60+ yrs | 19 | 3.3 (3.1, 3.5) | -- | -- |
| | Male | 17 | 3.8 (3.5, 4.1) | -- | -- |
| | Female | 16 | 3.7 (3.5, 3.9) | -- | -- |
| 46 | Martial Arts/Dancing | 2 | 2.7 (2.5, 2.9) | 15670 15430 03010 | Tai Chi 4.0 Karate/Jujitsu/ Kickboxing/ Tae kwan do 10.0 Dancing 4.8 |
| 48 | Boxing (punching bag) | 1 | 5.4 | 15110 | 6.0 |
| 50 | Other | 3 | 4.5 (4.2, 4.8) | -- | -- |
| | Petanque | 1 | 4.4 | -- | -- |
| | Trampoline | 1 | 6.1 | 15700 | 3.5 |

**Table 49.** NZ vs. US Mean METs for Ball Games

| NZPAQ CODE | BALL GAMES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 5 | Basketball | 5 | 5.8<br>(5.4, 6.2) | 15050 | 6.0 |
| 6 | Bowls - outdoor/lawn | 2 | 3.2<br>(3.18, 3.22) | 15570 | 3.0 |
| 7 | Bowls - indoor | 1 | 3.7 | 15090 | 3.0 |
| 16 | Golf | 2 | 5.3<br>(5.0, 5.6) | 15255 | 4.5 |
| 23 | Rugby - union | 2 | 8.3<br>(8.1, 8.5) | 15560 | 10.0 |
| 25 | Rugby - touch | 2 | 6.4<br>(5.6, 7.2) | -- | -- |
| 29 | Soccer | 5 | 7.0<br>(6.7, 7.3) | 15610 | 7.0 |
| 35 | Tennis | 3 | 5.8<br>(5.5, 6.1) | 15675 | 7.0 |
| 38 | Volleyball | 1 | 3.0 | 15720 | 3.0 |

**Table 50.** NZ vs. US Mean METs for Water Activities

| NZPAQ CODE | WATER ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 2 | Aquarobics | 2 | 5.9<br>(5.5, 6.3) | 18355 | 4.0 |
| 34 | Swimming | 12 | 5.9<br>(5.5, 6.3) | 18310<br>18240<br>18230 | General (no laps) 6.0<br>Laps (lt, mod) 7.0<br>Laps (vig) 10.0 |
| | 18-39 yrs | 3 | 7.1<br>(6.9, 7.3) | -- | -- |
| | 40-59 yrs | 6 | 6.8<br>(6.6, 7.0) | -- | -- |
| | 60+ yrs | 3 | 3.0<br>(2.8, 3.2) | -- | -- |
| | Male | 10 | 6.6<br>(6.3, 6.9) | -- | -- |
| | Female | 2 | 2.6<br>(2.5, 2.7) | -- | -- |

### 4.4.2 Transportation Physical Activities

Mean MET levels for activities performed for the purpose of transportation are presented in Table 51. Only 5 episodes of transportation PA were captured during the 3-day HRM period. An average of 2.6 METs was calculated for 4 sessions of walking to get from one place to another, which coincided with the 2.5 METs reported in the US Compendium.

**Table 51.** NZ vs. US Mean METs for Transportation Activities

| NZPAQ CODE | TRANSPORTATIONAL ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 200 | Walking | 4 | 2.6 (2.5, 2.7) | 17161 | 2.5 |
| 203 | Other | 1 | 4.0 | -- | -- |

### 4.4.3 Occupation Physical Activities

Table 52 lists mean MET levels for activities performed on the job during HRM compared to MET levels in the US Compendium.[24] The only occupational activity that showed similar MET values was moderate walking (3.5 vs. 3.3 METs).

Subgroup Analyses

Only 2 occupational PAs (‘Moving/Lifting/Carrying heavy loads’ and ‘Walking’) were performed frequently enough to warrant subgroup analyses. Males and participants in younger age groups performed both PAs at higher MET levels. ‘Moving/Lifting/Carrying heavy loads’ was captured as a moderate-intensity activity for males, and light-intensity for females. Amongst different age groups, intensity categories remain unchanged.

**Table 52.** NZ vs. US Mean METs for Occupational Activities

| NZPAQ CODE | OCCUPATIONAL ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 300 | Carrying light loads (walking) | 2 | 3.4<br>(3.3, 3.5) | 11795<br>11800<br>11810 | Slow 3.0<br>Moderate 4.0<br>Brisk 4.5 |
| 301 | Moving/Lifting light loads (standing) | 4 | 5.0<br>(4.8, 5.2) | 11610 | 3.0 |
| 302 | Moving/Lifting/Carrying heavy loads | 12 | 4.2<br>(4.0, 4.4) | 11050<br>11630 | Carry 8.0<br>Move/Lift 4.0 |
| | 18-39 yrs | 4 | 5.5<br>(5.4, 5.6) | -- | -- |
| | 40-59 yrs | 8 | 3.5<br>(3.4, 3.6) | -- | -- |
| | 60+ yrs | 0 | -- | -- | -- |
| | Male | 10 | 4.5<br>(4.3, 4.7) | -- | -- |
| | Female | 2 | 2.9<br>(2.8, 3.0) | -- | -- |
| 303 | Walking | 13 | 3.5<br>(3.4, 3.6) | 11791<br>11792<br>11793 | Very slow 2.0<br>Moderate 3.3<br>Brisk 3.8 |
| | 18-39 yrs | 0 | -- | -- | -- |
| | 40-59 yrs | 8 | 3.7<br>(3.6, 3.8) | -- | -- |
| | 60+ yrs | 5 | 3.1<br>(3.0, 3.2) | -- | -- |
| | Male | 12 | 3.5<br>(3.4, 3.6) | -- | -- |
| | Female | 1 | 3.3 | -- | -- |
| 305 | Light/Moderate cleaning | 3 | 2.3<br>(2.2, 2.4) | 11125 | Moderate 3.5 |
| 306 | Other (lawn mowing, planting) | 4 | 3.9<br>(3.6, 4.2) | 08095<br>08140/<br>08150 | General mowing 5.5<br>Planting 4.5 |

### 4.4.4 Other/Incidental, Household, Lawn and Garden Physical Activities

Mean MET levels for Other/Incidental, household, lawn and garden PAs, compared to the US Compendium,[24] are presented in Tables 53, 54, and 55, respectively. General cleaning (2.9 METs) was well-matched with the US Compendium (3.0 METs). Incidental/Other and household PAs captured during HRM were generally performed at greater intensities than those listed in the US Compendium.[24] Intensity classifications based on mean METs were in disagreement for the following PAs:

- Coaching sport: 8.0 METs in current study vs. 4.0 METs in US Compendium
- Kitchen activity: 3.4 METs in current study vs. 2.2 METs in US Compendium
- Religious/Church activity: 3.4 METs in current study vs. 1.8 METs in US Compendium
- Self care: 3.9 METs in current study vs. 2.0 METs in US Compendium
- Socialising/Eating: 3.4 METs in current study vs. 1.8 METs in US Compendium

Three PAs performed in the other/incidental context during HRM, which were not listed in the US Compendium,[24] were:

- Carry heavy loads: 4.0 METs (moderate)
- Carry light/moderate loads: 4.5 METs (moderate)
- Home repair: 5.7 METs (moderate)

Subgroup Analyses

Male and younger participants (<60 yrs) performed the following five Other/Incidental, Household and Lawn and Garden PAs at higher intensities:

- Gardening
- General cleaning
- Self care
- Socialising/Eating
- Walking – light, non-cleaning (ready to leave, shut/lock doors, close windows

Self care and socialising/eating were classified as moderate-intensity PAs compared to light-intensity on the US Compendium,[24] and were classified as vigorous-intensity when performed by the 18-39 yrs age group.

**Table 53.** NZ vs. US Mean METs for Other/Incidental Activities

| NZPAQ CODE | OTHER/INCIDENTAL ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 407 | Playing with children | 3 | 2.2<br>(2.1, 2.3) | 05170<br>05171 | 2.5<br>2.8 |
| 408 | Carrying light to moderate loads | 4 | 4.5<br>(4.0, 5.0) | | |
| 409 | Carrying heavy loads | 4 | 4.0<br>(3.9, 4.1) | | |
| 413 | Coaching sport | 1 | 8.0 | 15140 | 4.0 |
| 414 | Emotion/Stress/Sport spectator | 4 | 3.3<br>(3.1, 3.5) | 09115 | 1.5 |
| 415 | Socialising/Eating | 15 | 3.4<br>(3.1, 3.7) | 13030/09100<br>13035 | Sit 1.5<br>Stand 2.0 |
| | 18-39 yrs | 1 | 7.6 | -- | -- |
| | 40-59 yrs | 5 | 3.8<br>(3.5, 4.1) | -- | -- |
| | 60+ yrs | 9 | 2.6<br>(2.4, 2.8) | -- | -- |
| | Male | 7 | 4.3<br>(3.9, 4.7) | -- | -- |
| | Female | 8 | 2.6<br>(2.4, 2.8) | -- | -- |
| 416 | Religious/Church activity | 7 | 3.4<br>(3.2, 3.6) | 20005<br>20020 | Sit 1.5<br>Stand 2.0 |

**Table 54.** NZ vs. US Mean METs for Household Activities

| NZPAQ CODE | HOME ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 400 | General cleaning | 31 | 2.9 (2.7, 3.1) | 05030 | 3.0 |
| | 18-39 yrs | 3 | 4.3 (4.0, 4.6) | -- | -- |
| | 40-59 yrs | 8 | 3.5 (3.4, 3.6) | -- | -- |
| | 60+ yrs | 20 | 2.5 (2.3, 2.7) | -- | -- |
| | Male | 11 | 3.2 (2.9, 3.5) | -- | -- |
| | Female | 20 | 2.8 (2.6, 3.0) | -- | -- |
| 401 | Walking - light, non-cleaning (ready to leave, shut/lock doors, close windows) | 15 | 3.4 (3.2, 3.6) | 05165 | 3.0 |
| | 18-39 yrs | 1 | 5.3 | -- | -- |
| | 40-59 yrs | 10 | 3.6 (3.4, 3.8) | -- | -- |
| | 60+ yrs | 4 | 2.7 (2.6, 2.8) | -- | -- |
| | Male | 2 | 4.9 (4.8, 5.0) | -- | -- |
| | Female | 13 | 3.2 (3.0, 3.4) | -- | -- |
| 403 | Self care | 13 | 3.9 (3.5, 4.3) | 13020<br>13040 | Un/dressing 2.0<br>Grooming 2.0 |
| | 18-39 yrs | 3 | 6.4 (6.1, 6.7) | -- | -- |
| | 40-59 yrs | 5 | 4.0 (3.7, 4.3) | -- | -- |
| | 60+ yrs | 5 | 2.3 (2.2, 2.4) | -- | -- |
| | Male | 4 | 4.6 (4.1, 5.1) | -- | -- |
| | Female | 9 | 3.6 (3.3, 3.9) | -- | -- |
| 404 | Moving furniture | 1 | 5.7 | 05120 | 6.0 |
| 405 | Multiple household activities (moderate) | 4 | 4.3 (4.0, 4.6) | 05026 | 3.5 |

| NZPAQ CODE | HOME ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 410 | Home repair | 2 | 5.7<br>(5.5, 5.9) | | |
| 412 | Childcare | 2 | 2.8<br>(2.7, 2.9) | 05185/21016<br>05186/21017 | Sitting 2.5<br>Standing 3.0 |
| 418 | Kitchen activity - cooking, washing dishes | 8 | 3.4<br>(3.2, 3.6) | 05041<br>05050 | Dishes 2.3<br>Food prep 2.0 |
| 421 | Other (un/packing, non-church singing, shopping, playing instrument, laundry, auto repair, board games, caring for animals, take out rubbish) | 11 | 2.4<br>(2.2, 2.6) | 05090<br>20020<br>05065<br>10050<br>06030<br>09010<br>05053<br>11127 | Laundry 2.0<br>Singing 2.0<br>Shop/walk 2.3<br>Flute 2.0<br>Auto repair 3.0<br>Board game 1.5<br>Animal care 2.5<br>Rubbish 3.0 |
| | 18-39 yrs | 1 | 2.1 | -- | -- |
| | 40-59 yrs | 5 | 3.1<br>(2.8, 3.4) | -- | -- |
| | 60+ yrs | 5 | 1.7<br>(1.6, 1.8) | -- | -- |
| | Male | 4 | 3.1<br>(2.8, 3.4) | -- | -- |
| | Female | 7 | 2.0<br>(1.8, 2.2) | -- | -- |

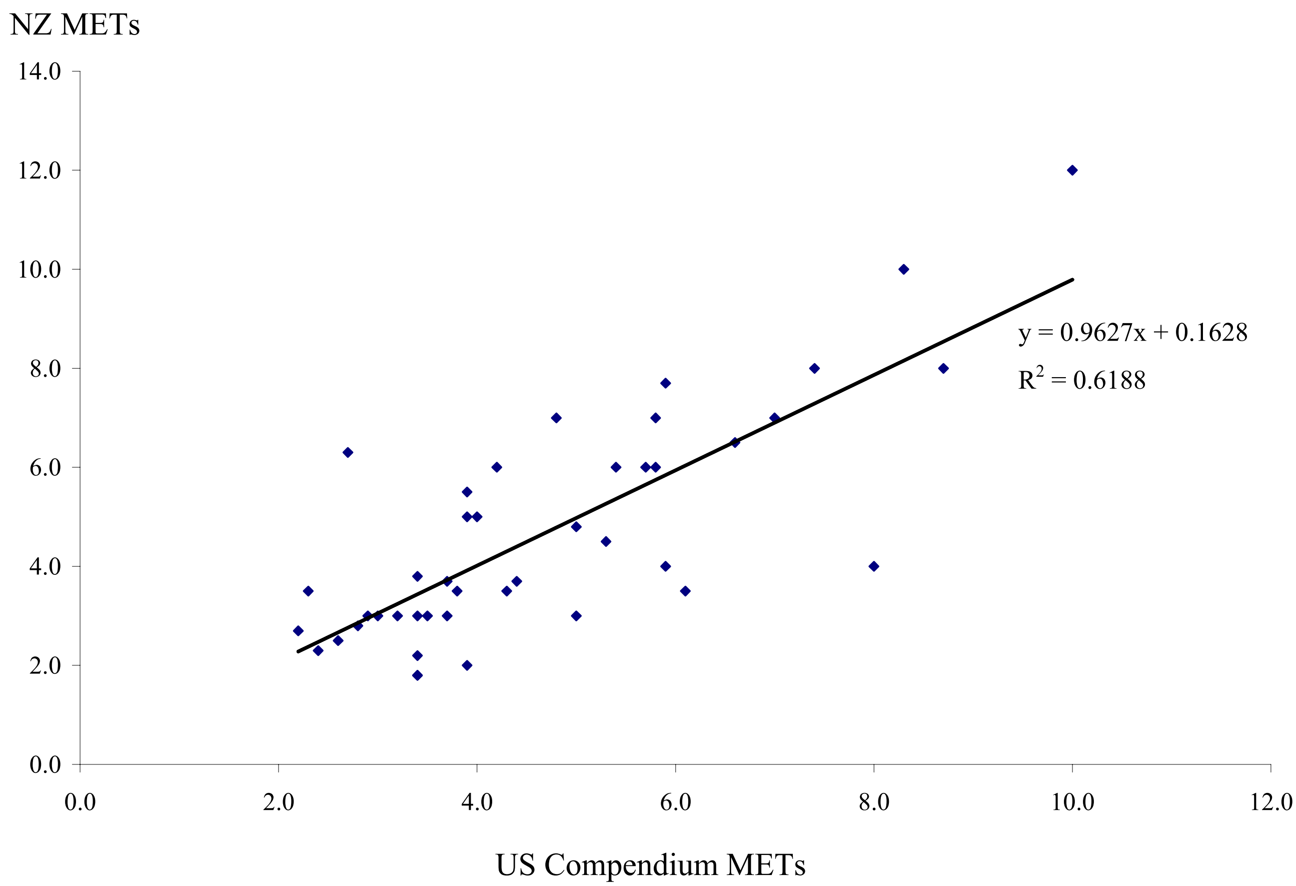
**Table 55.** NZ vs. US Mean METs for Lawn and Garden Activities

| NZPAQ CODE | LAWN AND GARDEN ACTIVITIES | N | Mean METs in NZ (95% CI) | U.S. CODE | Mean METs US Compendium |
|---|---|---|---|---|---|
| 15 | Gardening | 22 | 4.0 (3.7, 4.3) | 08245 | 5.0 |
| | 18-39 yrs | 2 | 5.0 (4.8, 5.2) | -- | -- |
| | 40-59 yrs | 3 | 3.8 (3.5, 4.1) | -- | -- |
| | 60+ yrs | 18 | 3.9 (3.6, 4.2) | -- | -- |
| | Male | 16 | 4.1 (3.8, 4.4) | -- | -- |
| | Female | 7 | 3.8 (3.6, 4.0) | -- | -- |
| 406 | Lawn mowing | 3 | 3.9 (3.5, 4.3) | 08095 | 5.5 |

### 4.4.5 Summary of Comparison between METs: NZ vs. US Compendium

The list of New Zealand (NZ) activities are broadly classified, while the US Compendium provides MET values for very specific PA modes. In some cases, multiple PAs from the US instrument, which corresponded to activities performed by the NZ sample (Tables 48-55), were used to calculate comparable EE rates. Overall, NZ MET values were slightly higher, although still strongly correlated with the US Compendium (Figure 14).

**Figure 9.** Correlation between METs Measured in NZ and US Compendium



### 4.4.6 New Zealand Cultural Physical Activities

Description of Māori Physical Activities

The full programme of Te Roopu Manutaki's kapahaka competition included the following[166]:

- **Kapahaka** – refers to the entire set of Māori traditional performing arts activities, and the group they are performed by. The term 'kapa' refers to ranks or rows, and combined with 'haka' it means ranks or rows doing the haka forms. In a contemporary sense it is held to mean a group that practices the Māori performing arts.

- **Taiaha** – teaches the art of combat and involves literally hundreds of combined movements of the feet, hands and long club weapon. It is very physical and requires moderate to high levels of energy. Note: The term 'Mau Rakau' may be used, referring generally to any (wooden, stone, or bone) Māori weapon.

- **Waiata-ā-ringa** – referred to as the action song, involves group movements in unison. A medium level of energy is required.

- **Whakaeke** – performed as a means of entering the stage, making an impression on the audience and grabbing their attention. The entrance can include singing or 'Haka' type activity, although usually a combination of the two are performed. This can be a vigorous-intensity activity, and requires a medium to high energy level.

- **Mōteatea** - a traditional chant, emphasising simultaneous pronunciation and interpretation expressed through bodily movements. Although a number of chants exist, they do not normally require much physical effort, and therefore involve a low to moderate energy level.

- **Haka** – the most physically demanding activity, involving hands, feet, legs, body, voice, tongue and eyes to express passion and vigour. In haka the whole body comes into play, particularly the facial expressions, which can illustrate the meaning of the words quite graphically. Haka is normally performed by males, although females lend vocal support.

- **Haka Pōwhiri** – the haka of welcome. Although less intense than the Haka, the Haka Pōwhiri is performed vigorously by both males and females.

- **Haka Tūtūngurahu** – the haka of war. A confrontational form of the Haka performed by males and females.

- **Waiata Tira** – fairly motionless singing and harmonising with a number of parts (i.e. base, tenor, soprano, descant). This may involve some stage formations, but requires little physical effort, as the focus is on the music and the song. Recently, Waiata Tira has been used by some groups either as a warm-up or as a humorous piece.

- **Whakawhiti** – a short, transitional activity performed to simultaneously move the males and females to the front and rear of the stage, respectively, so that males can perform the Haka. This is a medium to high energy activity.

- **Poi** – a dance performed solely by females, involving movements with one or two poi to express song interpretation. Poi refers to a string with a ball at one end, and can be single or double short or single, double or quadruple long. Poi is performed in unison as a group, and requires more mental focus then physical exertion, as the motion primarily originates from the wrists and elbows.

- **Whakawātea -** This activity is similar to the 'Whakaeke', but refers to exiting the stage. It is the final opportunity to impress the audience and is often a combination of Waiata-a-ringa and Haka activity, requiring medium to high levels of energy.

<u>METs for Māori Activities</u>

In addition to assigning a MET level to the overall kapahaka practice performed by Te Roopu Manutaki at the Hoani Waititi Marae, METs for eleven individual kapahaka activities were captured during HRM (Table 56). Analyses by gender revealed kapahaka PAs were more strenuous for males (6.2 METs) compared to females (3.9 METs). All male kapahaka PAs were classified as vigorous-intensity (>6 METs), with the exception of Waiata-ā-ringa (5.9 METs), Mōteatea (5.0 METs), and Waiata Tira (5.4 METs). Female kapahaka PAs were of moderate-intensity (3-6 METs), with the exception of Haka Tūtūngurahu (2.7 METs), classified as a light-intensity activity.

No kapahaka performers were aged 60+ yrs, although a 78 year old female participant (not a member of Te Roopu Manutaki) performed kapahaka in a different setting, and was classified as light-intensity (2.0 METs). Mean METs were consistently higher in the 18-39 yrs age group compared to the 40-59 yrs age group, with an average difference of 1.2 METs for all kapahaka activities.

Pacific Island Dance

Cook Island Dance was performed once by one female participant, providing a baseline of 4.3 METs (moderate-intensity) for this activity. Another female participant performed Tongan Dance on two separate occasions during her HRM period, averaging 1.9 METs (light-intensity). The three sessions of Cook Island and Tongan dance were combined into a 'Pacific Island Dance' category and classified as light-intensity activity (2.7 METs) (Table 56).

**Table 56.** Mean METs for NZ Māori and Pacific Activities

| NZPAQ CODE | CULTURAL ACTIVITIES | N | Average METs (95% CI) | | NZPAQ CODE | CULTURAL ACTIVITIES | N | Average METs (95% CI) |
|---|---|---|---|---|---|---|---|---|
| 42 | Kapahaka | 27 | 4.9 (4.6, 5.2) | | -- | Waiata-ā-ringa | 35 | 4.9 (4.5, 5.3) |
| | 18-39 yrs | 16 | 4.2 (4.0, 4.4) | | | 18-39 yrs | 20 | 5.4 (5.0, 5.8) |
| | 40-59 yrs | 10 | 3.8 (3.6, 4.0) | | | 40-59 yrs | 15 | 4.3 (4.0, 4.6) |
| | 60+ yrs | 1 | 2.0 | | | 60+ yrs | 0 | -- |
| | Male | 12 | 6.2 (5.9, 6.5) | | | Male | 17 | 5.9 (5.6, 6.2) |
| | Female | 15 | 3.9 (3.7, 4.1) | | | Female | 18 | 4.0 (3.7, 4.3) |
| 43 | Taiaha | 22 | 6.4 (6.1, 6.7) | | -- | Whakaeke | 20 | 5.4 (4.9, 5.9) |
| | 18-39 yrs | 16 | 6.9 (6.6, 7.2) | | | 18-39 yrs | 11 | 6.0 (5.3, 6.7) |
| | 40-59 yrs | 6 | 5.0 (4.9, 5.1) | | | 40-59 yrs | 9 | 4.6 (4.2, 5.0) |
| | 60+ yrs | 0 | -- | | | 60+ yrs | 0 | -- |
| | Male | 15 | 7.1 (6.8, 7.4) | | | Male | 13 | 6.3 (5.8, 6.8) |
| | Female | 7 | 5.0 (4.9, 5.1) | | | Female | 7 | 3.6 (3.4, 3.8) |

Light = <3 METs, Moderate = 3-6 METs, Vigorous = >6 METs

| NZPAQ CODE | CULTURAL ACTIVITIES | N | Average METs (95% CI) | | NZPAQ CODE | CULTURAL ACTIVITIES | N | Average METs (95% CI) |
|---|---|---|---|---|---|---|---|---|
| -- | Mōteatea | 13 | 4.3 (3.9, 4.7) | | -- | Haka Pōwhiri | 11 | 5.8 (5.2, 6.4) |
| | 18-39 yrs | 7 | 4.8 (4.4, 5.2) | | | 18-39 yrs | 5 | 6.6 (5.8, 7.4) |
| | 40-59 yrs | 6 | 3.7 (3.4, 4.0) | | | 40-59 yrs | 6 | 5.2 (4.8, 5.6) |
| | 60+ yrs | 0 | -- | | | 60+ yrs | 0 | -- |
| | Male | 5 | 5.0 (4.5, 5.5) | | | Male | 5 | 8.5 (8.1, 8.9) |
| | Female | 8 | 3.9 (3.6, 4.2) | | | Female | 6 | 5.3 (5.1, 5.5) |
| -- | Haka | 10 | 7.1 (6.8, 7.4) | | -- | Haka Tūtūngurahu | 21 | 5.4 (4.9, 5.9) |
| | 18-39 yrs | 6 | 7.9 (7.6, 8.2) | | | 18-39 yrs | 11 | 6.3 (5.7, 6.9) |
| | 40-59 yrs | 4 | 5.9 (5.7, 6.1) | | | 40-59 yrs | 10 | 4.4 (4.0, 4.8) |
| | 60+ yrs | 0 | -- | | | 60+ yrs | 0 | -- |
| | Male | 10 | 7.1 (6.8, 7.4) | | | Male | 15 | 6.5 (6.1, 6.9) |
| | Female | 0 | -- | | | Female | 6 | 2.7 (2.5, 2.9) |

Light = <3 METs, Moderate = 3-6 METs, Vigorous = >6 METs

| NZPAQ CODE | CULTURAL ACTIVITIES | N | Average METs (95% CI) | | NZPAQ CODE | CULTURAL ACTIVITIES | N | Average METs (95% CI) |
|---|---|---|---|---|---|---|---|---|
| -- | Waiata Tira | 21 | 5.0 (4.6, 5.4) | | -- | Poi | 15 | 4.6 (4.4, 4.8) |
| | 18-39 yrs | 12 | 5.4 (5.0, 5.8) | | | 18-39 yrs | 10 | 4.9 (4.7, 5.1) |
| | 40-59 yrs | 9 | 4.4 (4.1, 4.7) | | | 40-59 yrs | 5 | 4.0 (3.7, 4.3) |
| | 60+ yrs | 0 | -- | | | 60+ yrs | 0 | -- |
| | Male | 15 | 5.4 (5.0, 5.8) | | | Male | 0 | -- |
| | Female | 6 | 3.7 (3.5, 3.9) | | | Female | 15 | 4.6 (4.4, 4.8) |
| -- | Whakawhiti | 12 | 5.7 (5.3, 6.1) | | -- | Whakawātea | 23 | 5.5 (5.1, 5.9) |
| | 18-39 yrs | 7 | 5.8 (5.2, 6.4) | | | 18-39 yrs | 14 | 5.8 (5.3, 6.3) |
| | 40-59 yrs | 5 | 5.4 (5.2, 5.6) | | | 40-59 yrs | 9 | 5.1 (4.8, 5.4) |
| | 60+ yrs | 0 | -- | | | 60+ yrs | 0 | -- |
| | Male | 7 | 7.0 (6.7, 7.3) | | | Male | 9 | 6.7 (6.3, 7.1) |
| | Female | 5 | 3.8 (3.6, 4.0) | | | Female | 14 | 4.7 (4.4, 5.0) |
| | | | | | 417 | Pacific Island Dance | 3 | 2.7 (2.4, 3.0) |

Light = <3 METs, Moderate = 3-6 METs, Vigorous = >6 METs

## 4.5 CARDIORESPIRATORY FITNESS AND PHYSICAL ACTIVITY: RELATIONSHIPS TO CARDIOVASCULAR RISK FACTORS

Multiple linear regression analyses were performed to examine any differences in the relationships of PA and CRF in regard to CV risk factors, including BMI, hypertension, and fasting blood lipids.

### 4.5.1 Comparison of Participants with and without Blood Tests

Regression models for blood variables were performed on 92 participants, as the fasting blood test was optional. Mean values are listed in Table 57, with corresponding threshold levels for heart disease.[25,91] Overall, the sample's blood test results showed elevated levels of total cholesterol (TC). Impaired fasting glucose was observed in 11 participants (5 male, 6 female, mean age 62.7 ± 14.7 yrs). This group consisted of 3 European/Other, 6 Māori, and 2 Pacific participants.

Chi-squared analyses showed significant differences between participants, who did and did not choose to receive the free blood test, in ethnicity ($p=0.001$), PA levels ($p=0.01$), and smoking ($p<0.001$) (Table 58). The sample of participants who volunteered for the blood test consisted mainly of European/Other and individuals (mean age = 50.9 yrs), who were non-smokers. The sample that chose not to receive the blood test was primarily Pacific individuals (mean age = 46.3 yrs), who were smokers, yet the majority of these participants were meeting current PA guidelines and accumulating at least 150 minutes of moderate-intensity PA per week. Mean BMI for participants with and without blood results were 30.0 $kg \cdot m^{-2}$ and 30.8 $kg \cdot m^{-2}$, respectively, and mean SBP/DBP was 125/78 mmHg and 129/79 mmHg, respectively.

**Table 57.** Blood Lipid and Glucose Profiles for Fasting Blood Test (n=92)

| **Blood Variable** | **Mean Value (SD) (mmol/L)** | **Risk Factor Thresholds[25,91] (mmol/L)** |
|---|---|---|
| Triglycerides (TG) | 1.4 (0.8) | > 1.7 |
| HDL-Cholesterol | 1.4 (0.4) | < 0.9 |
| LDL-Cholesterol | 3.1 (0.9) | > 3.4 |
| Total Cholesterol (TC) | 5.3 (1.0) | > 5.2 |
| Glucose | 5.4 (1.3) | > 6.1 |

**Table 58.** Comparison of Participants with and without Blood Test Results

| | Blood Test | | |
|---|---|---|---|
| | **Yes (n=92) (%)** | **No (n=94) (%)** | **p-value** |
| **Age (yrs)** | | | |
| 18-39 | 27.2 | 41.5 | 0.09 |
| 40-59 | 33.7 | 30.9 | |
| 60+ | 39.1 | 27.7 | |
| **Ethnicity** | | | |
| European/Other | 42.4 | 22.3 | 0.001 |
| Māori | 34.8 | 30.9 | |
| Pacific | 22.8 | 46.8 | |
| **Gender** | | | |
| Male | 45.7 | 51.1 | 0.46 |
| Female | 54.3 | 48.9 | |
| **BMI ($kg \cdot m^{-2}$)** | | | |
| Obese[1] | 34.8 | 44.7 | 0.26 |
| Overweight[2] | 35.9 | 35.1 | |
| Normal weight | 29.4 | 20.2 | |
| **Hypertension (mmHg)[25]** | | | |
| SBP > 140 | 18.5 | 23.4 | 0.41 |
| DBP > 90 | 14.1 | 18.1 | 0.46 |
| **PA Level (min/week)** | | | |
| PA < 150 | 49.4 | 32.3 | 0.01 |
| PA ≥ 150 | 50.6 | 67.7 | |
| **Smoking Habit** | 10.9 | 30.9 | < 0.001 |

[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

The combination of age, ethnicity and gender served as the base model (Model 1) for each analysis, which was performed on the following CV risk factors:

- BMI (Table 59)
- SBP (Table 60)
- DBP (Table 61)
- TG (Table 62)
- HDL-Cholesterol (Table 63)
- LDL-Cholesterol (Table 64)
- TC (Table 65)
- TC/HDL-cholesterol Ratio (Table 66)
- Fasting Glucose (Table 67)

### 4.5.2 Overweight/Obesity

Ethnic differences remained highly significant ($p<0.001$) throughout every linear regression model, and adjusting for $VO_{2max}$ revealed significant associations with demographic variables ($p<0.01$), independent of PA (Table 59). This suggests ethnic differences in BMI are independent of PA.

### 4.5.3 Hypertension

Systolic Blood Pressure

It is well-known that older individuals are more likely to have higher SBP. Multiple linear regression models for SBP are shown in Table 60. Participants aged 40+ had consistently significantly higher SBP compared to participants aged 18-39 yrs. Male and Pacific participants had consistently higher SBP compared to their female, European/Other and Māori counterparts, respectively. Adjusting for BMI significantly increased ethnic differences and decreased gender differences, while PA increased age and ethnic differences but decreased gender differences. $VO_{2max}$ and smoking had minimal effects on the base model variables and were omitted from the final model.

Diastolic Blood Pressure

Similar to SBP, participants aged 40+ years, and of Pacific ethnicity, had consistently higher DBP compared to participants aged 18-39 yrs, European/Other and Māori, respectively (Table 61). Adjusting for BMI, PA or smoking had no major effect on the base model variables, while the addition of $VO_{2max}$ slightly decreased age and ethnic differences, and increased gender differences.

### 4.5.4 Fasting Blood Lipids and Glucose

Triglycerides

Although no significant age, gender, or ethnic differences were observed in TG levels, overweight, obesity, and $VO_{2max}$ revealed significant associations (Table 62). However, this relationship was stronger for BMI, which increased ethnic differences and accounted for an extra 10% of the variation in triglycerides, compared to an extra 4% for $VO_{2max}$. Physical activity (Model 3) and smoking (Model 5) had negligible associations with triglycerides, and were therefore omitted from the further analyses. The final model, including age, gender, ethnicity, BMI and $VO_{2max}$, explained 15% of the variation in triglyceride levels. Obesity ($p<0.01$) and overweight ($p<0.05$) were the only significant correlates of triglycerides. However, Pacific ethnicity nearly reached significance ($p=0.07$), while the slight change in $VO_{2max}$ resulted in a loss of significance. The addition of BMI in Models 2 and 6 indicates that the inverse association between TG and $VO_{2max}$ is partly mediated by BMI.

HDL-Cholesterol

The base model identified gender and ethnicity as significantly related variables to HDL-cholesterol levels, as gender differences in HDL-cholesterol remained significant ($p<0.001$) and unchanged throughout each model, while ethnic differences were dramatically decreased to a nonsignificant level when adjusted for BMI (Table 63). The latter finding indicates that ethnic differences in BMI explain most of the ethnic differences in HDL-cholesterol. Ethnic differences also decreased when adjusting for $VO_{2max}$ ($p=0.06$), but were unaffected by the addition of PA or smoking. Adjusting for BMI had the greatest effect on the base model, accounting for an additional 14% of variation in HDL-cholesterol. In the final model, gender, obesity, overweight, and smoking showed significant associations with HDL-cholesterol, and vigorous-intensity PA nearly reached significance ($p=0.05$).

LDL-Cholesterol

The linear regression analyses for LDL-cholesterol identified smoking as the only significantly related variable when added to the base model, although $VO_{2max}$ was borderline significant ($p=0.05$) (Table 64). BMI, PA, and $VO_{2max}$ were included in the final regression model, as each showed a slight increase in $R^2$. Smoking remained the only significant variable in the final model, with $VO_{2max}$ nearly reaching statistical significance ($p=0.06$)

Total Cholesterol

No significant relationships to TC were revealed when adjusting for age, gender and ethnicity (Table 65). $VO_{2max}$ was the only variable significantly related ($p<0.05$) to TC, and was not confounded by BMI in the final regression model.

Ratio of Total Cholesterol/HDL-Cholesterol

Gender was a consistently significant variable throughout the multiple linear regression models for the TC/HDL-cholesterol ratio (Table 66). When added to the base model, obesity, overweight, $VO_{2max}$ and smoking showed significant associations ($p<0.01$) to TC/HDL-cholesterol, and remained significant in the final regression model. BMI appeared to have the greatest impact on the base model, contributing to an additional 11% or explained variation in TC/HDL-cholesterol. Moderate- and vigorous-intensity PA had little effect on the base model, but participation in >15 min/day of vigorous-intensity PA was significant ($p<0.05$) in the final model.

Fasting Glucose

Multiple linear regression models for fasting glucose are presented in Table 67. Age (60+ yrs) and ethnicity (Pacific) were consistently significant throughout all regression models, with the exception of ethnicity in the final model ($p=0.06$). None of the additional variables showed significant associations with fasting glucose levels.

**Table 59.** Linear Regression Models for Body Mass Index (N=186)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.23 | 0.25 | 0.31 | 0.24 | 0.31 | |
| | | | | **Mean difference in kg·m$^{-2}$ (SE)** | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 1.4 (1.0) | 1.3 (1.1) | 0.3 (1.0) | 1.4 (1.0) | 0.3 (1.0) | |
| | 60+ | 1.5 (1.0) | 1.2 (1.1) | -0.2 (1.1) | 1.4 (1.0) | -0.3 (1.1) | |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | 5.8 (1.1)*** | 5.8 (1.1)*** | 4.9 (1.0)*** | 5.8 (1.1)*** | 5.0 (1.1)*** | |
| | Pacific | 7.2 (1.0)*** | 7.0 (1.1)*** | 5.9 (1.0)*** | 7.2 (1.0)*** | 5.8 (1.1)*** | |
| Gender | Male | -0.4 (0.9) | -0.2 (0.9) | 0.8 (0.9) | -0.3 (0.9) | 0.8 (0.9) | |
| | Female | -- | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | -0.4 (1.1) | | | -0.2 (1.0) | |
| | 30-60 | | -0.6 (1.1) | | | -0.7 (1.1) | |
| | < 30 | -- | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | -0.8 (1.1) | | | -0.5 (1.0) | |
| | 1-15 | | 1.1 (1.3) | | | 1.2 (1.2) | |
| | 0 | -- | -- | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | -0.2 (0.04)*** | | -0.2 (0.04)*** | |
| Smoking | Yes | | | | -0.8 (1.1) | | |
| | No | -- | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category

**Table 60.** Linear Regression Models for Systolic Blood Pressure (N=186)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.14 | 0.16 | 0.16 | 0.14 | 0.15 | 0.18 |
| | | **Mean difference in mmHg (SE)** | | | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 8.8 (3.3** | 8.9 (3.4)** | 9.4 (3.3)** | 8.6 (3.4)* | 8.9 (3.3)** | 9.5 (3.4)** |
| | 60+ | 12.4 (3.3) *** | 12.4 (3.3)*** | 14.0 (3.5)*** | 12.0 (3.5)*** | 12.2 (3.3)*** | 13.8 (3.5)*** |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | 4.1 (3.4) | 5.0 (3.6) | 5.1 (3.5) | 4.0 (3.4) | 4.2 (3.4) | 5.8 (3.8) |
| | Pacific | 10.9 (3.3)** | 12.5 (3.6)*** | 12.7 (3.5)*** | 10.6 (3.5)** | 11.0 (3.3)** | 14.1 (3.8)*** |
| Gender | Male | 5.5 (2.7)* | 5.1 (2.7) | 4.8 (2.8) | 5.7 (2.9)* | 5.7 (2.7)* | 4.4 (2.8) |
| | Female | -- | -- | -- | -- | -- | -- |
| BMI ($kg{\cdot}m^{-2}$) | Obese[1] | | -4.2 (3.9) | | | | -3.6 (3.9) |
| | Overweight[2] | | 1.7 (3.8) | | | | 2.6 (3.9) |
| | Normal | -- | -- | -- | | -- | -- |
| Moderate PA (min/day) | > 60 | | | 1.0 (3.4) | | | 1.4 (3.3) |
| | 30-60 | | | 4.3 (3.5) | | | 4.3 (3.5) |
| | < 30 | -- | -- | -- | | -- | -- |
| Vigorous PA (min/day) | > 15 | | | 4.8 (3.3) | | | 5.0 (3.3) |
| | 1-15 | | | -0.7 (4.1) | | | -0.4 (4.1) |
| | 0 | -- | -- | -- | | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | -0.04 (0.1) | | |
| Smoking | Yes | | | | | -2.0 (3.4) | |
| | No | -- | -- | -- | -- | -- | -- |

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ compared to reference category

[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific

[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

**Table 61.** Linear Regression Models for Diastolic Blood Pressure (N=186)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.12 | 0.12 | 0.13 | 0.12 | 0.12 | 0.13 |
| | | | | **Mean difference in mmHg (SE)** | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 8.4 (2.3)*** | 8.6 (2.3)*** | 8.5 (2.3)*** | 8.2 (2.4)*** | 8.5 (2.3)*** | 8.2 (2.4)*** |
| | 60+ | 8.1 (2.3)*** | 8.3 (2.3)*** | 8.3 (2.4)*** | 7.7 (2.4)** | 8.0 (2.3)*** | 7.9 (2.6 )** |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | 3.5 (2.3) | 3.8 (2.5) | 3.8 (2.4) | 3.3 (2.4) | 3.5 (2.3) | 3.6 (2.5) |
| | Pacific | 5.5 (2.3)* | 5.8 (2.5)* | 5.9 (2.4)* | 5.2 (2.4)* | 5.5 (2.3)* | 5.6 (2.5)* |
| Gender | Male | 1.8 (1.9) | 1.8 (1.9) | 1.7 (1.9) | 2.1 (2.0) | 1.9 (1.9) | 2.0 (2.0) |
| | Female | -- | | -- | -- | -- | -- |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | -0.8 (2.7) | | | | |
| | Overweight[2] | | -1.0 (2.6) | | | | |
| | Normal | -- | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | 0.4 (2.3) | | | 0.5 (2.3) |
| | 30-60 | | | 1.8 (2.4) | | | 1.8 (2.5) |
| | < 30 | -- | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | 0.3 (2.3) | | | 0.4 (2.3) |
| | 1-15 | | | 0.1 (2.9) | | | 0.2 (2.9 |
| | 0 | -- | -- | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | -0.05 (0.1) | | -0.05 (0.1) |
| Smoking | Yes | | | | | -0.9 (2.3) | |
| | No | -- | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category
[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

**Table 62.** Linear Regression Models for Fasting Triglycerides (n=92)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.03 | 0.13 | 0.03 | 0.07 | 0.03 | 0.15 |
| | | | | **Mean difference in mmol/L (SE)** | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | -0.04 (0.23) | -0.12 (0.23) | -0.07 (0.25) | -0.12 (0.23) | -0.04 (0.23) | -0.16 (0.23) |
| | 60+ | 0.15 (0.25) | 0.07 (0.24) | 0.10 (0.26) | -0.02 (0.25) | 0.18 (0.25) | -0.03 (0.25) |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | 0.06 (0.21) | -0.24 (0.22) | 0.02 (0.23) | -0.08 (0.21) | 0.06 (0.21) | -0.31 (0.22) |
| | Pacific | -0.14 (0.25) | -0.40 (0.25) | -0.16 (0.27) | -0.26 (0.25) | -0.13 (0.25) | -0.46 (0.25) |
| Gender | Male | -0.02 (0.18) | -0.08 (0.17) | 0.003 (0.19) | 0.18 (0.20) | -0.01 (0.18) | 0.07 (0.20) |
| | Female | -- | -- | -- | -- | -- | -- |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | 0.78 (0.24)** | | | | 0.67 (0.24)** |
| | Overweight[2] | | 0.58 (0.23)* | | | | 0.51 (0.23)* |
| | Normal | -- | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | 0.03 (0.23) | | | |
| | 30-60 | | | 0.001 (0.24) | | | |
| | < 30 | -- | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | -0.15 (0.22) | | | |
| | 1-15 | | | -0.10 (0.30) | | | |
| | 0 | -- | -- | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | -0.02 (0.01)* | | -0.01 (0.01) |
| Smoking | Yes | | | | | 0.17 (0.30) | |
| | No | -- | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category

[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific

[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

**Table 63.** Linear Regression Models for HDL-Cholesterol (n=92)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.27 | 0.41 | 0.28 | 0.30 | 0.29 | 0.47 |
| | | **Mean difference in mmol/L (SE)** | | | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 0.002 (0.09) | 0.03 (0.08) | -0.0002 (0.09) | 0.03 (0.09) | 0.0004 (0.09) | 0.01 (0.09) |
| | 60+ | 0.06 (0.09) | 0.08 (0.09) | 0.05 (0.10) | 0.12 (0.10) | 0.04 (0.09) | 0.02 (0.10) |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | -0.27 (0.08)*** | -0.11 (0.08) | -0.28 (0.09)** | -0.22 (0.08)** | -0.26 (0.08)** | -0.11 (0.09) |
| | Pacific | -0.23 (0.09)* | -0.10 (0.09) | -0.22 (0.10)* | -0.19 (0.09) | -0.24 (0.09)* | -0.10 (0.10) |
| Gender | Male | -0.31 (0.07)*** | -0.28 (0.06)*** | -0.30 (0.07)*** | -0.37 (0.08)*** | -0.31 (0.07)*** | -0.31 (0.07)*** |
| | Female | -- | -- | -- | -- | -- | -- |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | -0.38 (0.09)*** | | | | -0.41 (0.09)*** |
| | Overweight[2] | | -0.25 (0.08)** | | | | -0.25 (0.09)** |
| | Normal | -- | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | 0.07 (0.09) | | | 0.10 (0.08) |
| | 30-60 | | | 0.04 (0.09) | | | 0.002 (0.08) |
| | < 30 | -- | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | -0.06 (0.08) | | | -0.15 (0.08) |
| | 1-15 | | | -0.04 (0.11) | | | -0.07 (0.10) |
| | 0 | -- | -- | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | 0.01 (0.004) | | 0.004 (0.004) |
| Smoking | Yes | | | | | -0.15 (0.11) | -0.21 (0.11)* |
| | No | -- | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category
[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

**Table 64.** Linear Regression Models for LDL-Cholesterol (n=92)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.05 | 0.06 | 0.08 | 0.09 | 0.11 | 0.19 |
| | | | | **Mean difference in mmol/L (SE)** | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 0.39 (0.26) | 0.32 (0.26) | 0.45 (0.27) | 0.30 (0.26) | 0.40 (0.25) | 0.34 (0.27) |
| | 60+ | -0.004 (0.27) | -0.08 (0.28) | 0.03 (0.28) | -0.17 (0.28) | 0.13 (0.27) | -0.03 (0.31) |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | -0.09 (0.23) | -0.11 (0.25) | 0.01 (0.25) | -0.23 (0.23) | -0.12 (0.22) | -0.15 (0.27) |
| | Pacific | -0.05 (0.27) | -0.10 (0.29) | 0.03 (0.30) | -0.17 (0.27) | 0.01 (0.27) | -0.08 (0.30) |
| Gender | Male | 0.21 (0.20) | 0.18 (0.20) | 0.18 (0.21) | 0.41 (0.22) | 0.25 (0.19) | 0.40 (0.23) |
| | Female | -- | | -- | -- | -- | |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | 0.04 (0.28) | | | | 0.02 (0.29) |
| | Overweight[2] | | 0.25 (0.27) | | | | 0.13 (0.27) |
| | Normal | -- | | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | 0.13 (0.25) | | | 0.04 (0.25) |
| | 30-60 | | | -0.03 (0.26) | | | -0.11 (0.26) |
| | < 30 | -- | | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | 0.23 (0.24) | | | 0.34 (0.24) |
| | 1-15 | | | 0.39 (0.32) | | | 0.47 (0.31) |
| | 0 | -- | | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | -0.02 (0.01) | | -0.02 (0.01) |
| Smoking | Yes | | | | | 0.78 (0.32)* | 0.74 (0.33)* |
| | No | -- | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category
[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

**Table 65.** Linear Regression Models for Total Cholesterol (n=92)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.05 | 0.06 | 0.07 | 0.10 | 0.09 | 0.15 |
| | | **Mean difference in mmol/L (SE)** | | | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 0.38 (0.28) | 0.32 (0.29) | 0.42 (0.30) | 0.29 (0.28) | 0.39 (0.28) | 0.30 (0.30) |
| | 60+ | 0.12 (0.30) | 0.04 (0.31) | 0.10 (0.31) | -0.08 (0.31) | 0.23 (0.30) | -0.03 (0.34) |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | -0.26 (0.25) | -0.29 (0.28) | -0.22 (0.28) | -0.43 (0.26) | -0.29 (0.25) | -0.38 (0.30) |
| | Pacific | -0.36 (0.30) | -0.41 (0.32) | -0.29 (0.33) | -0.50 (0.30) | -0.30 (0.30) | -0.41 (0.34) |
| Gender | Male | -0.14 (0.22) | -0.17 (0.22) | -0.15 (0.23) | 0.09 (0.24) | -0.10 (0.22) | 0.10 (0.26) |
| | Female | -- | -- | -- | -- | -- | -- |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | 0.05 (0.31) | | | | -0.05 (0.32) |
| | Overweight[2] | | 0.25 (0.30) | | | | 0.10 (0.30) |
| | Normal | -- | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | 0.24 (0.28) | | | 0.18 (0.28) |
| | 30-60 | | | -0.01 (0.29) | | | -0.09 (0.29) |
| | < 30 | -- | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | 0.05 (0.27) | | | 0.14 (0.27) |
| | 1-15 | | | 0.28 (0.36) | | | 0.35 (0.35) |
| | 0 | -- | -- | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | -0.02 (0.01)* | | -0.03 (0.01)* |
| Smoking | Yes | | | | | 0.69 (0.36) | 0.58 (0.38) |
| | No | -- | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category
[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

**Table 66.** Linear Regression Models for Ratio of Total Cholesterol/HDL-Cholesterol (n=92)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.10 | 0.21 | 0.12 | 0.18 | 0.17 | 0.37 |
| | | | | **Mean difference in mmol/L (SE)** | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 0.03 (0.3) | -0.1 (0.3) | 0.1 (0.3) | -0.1 (0.3) | 0.04 (0.3) | -0.1 (0.3) |
| | 60+ | -0.3 (0.3) | -0.4 (0.3) | -0.3 (0.3) | -0.6 (0.3) | -0.1 (0.3) | -0.3 (0.3) |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | 0.5 (0.3) | 0.1 (0.3) | 0.6 (0.3)* | 0.3 (0.3) | 0.5 (0.3) | 0.07 (0.3) |
| | Pacific | 0.2 (0.3) | -0.1 (0.3) | 0.3 (0.4) | 0.03 (0.3) | 0.3 (0.3) | -0.1 (0.3) |
| Gender | Male | 0.6 (0.2)* | 0.5 (0.2)* | 0.6 (0.2)* | 0.9 (0.3)*** | 0.6 (0.2)** | 0.8 (0.3)** |
| | Female | -- | -- | -- | -- | -- | -- |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | 1.0 (0.3)** | | | | 1.0 (0.3)** |
| | Overweight[2] | | 0.9 (0.3)** | | | | 0.8 (0.3)* |
| | Normal | -- | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | -0.1 (0.3) | | | -0.2 (0.3) |
| | 30-60 | | | -0.1 (0.3) | | | -0.1 (0.3) |
| | < 30 | -- | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | 0.3 (0.3) | | | 0.6 (0.3)* |
| | 1-15 | | | 0.4 (0.4) | | | 0.5 (0.3) |
| | 0 | -- | -- | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | -0.04 (0.01)** | | -0.03 (0.01)* |
| Smoking | Yes | | | | | 1.0 (0.4)** | 1.1 (0.4)** |
| | No | -- | -- | -- | -- | -- | -- |

* p<0.05, **p<0.01, ***p<0.001 compared to reference category
[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific
[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

**Table 67.** Linear Regression Models for Fasting Glucose (n=92)

| | Model | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | $R^2$ | 0.15 | 0.18 | 0.17 | 0.19 | 0.15 | 0.23 |
| | | | | **Mean difference in mmol/L (SE)** | | | |
| Age (years) | 18-39 | -- | -- | -- | -- | -- | -- |
| | 40-59 | 0.4 (0.3) | 0.3 (0.3) | 0.3 (0.3) | 0.3 (0.3) | 0.4 (0.3) | 0.3 (0.4) |
| | 60+ | 1.0 (0.3)** | 1.0 (0.4)** | 1.1 (0.4)** | 0.9 (0.4)* | 1.1 (0.4)** | 0.9 (0.4)* |
| Ethnicity | Euro/Other | -- | -- | -- | -- | -- | -- |
| | Māori | 0.5 (0.3) | 0.3 (0.3) | 0.4 (0.3) | 0.4 (0.3) | 0.5 (0.3) | 0.1 (0.3) |
| | Pacific | 1.0 (0.4)** | 0.8 (0.4)* | 1.0 (0.4)** | 0.9 (0.4)* | 1.0 (0.4)** | 0.8 (0.4) |
| Gender | Male | 0.1 (0.3) | | | | | |
| | Female | -- | | -- | -- | -- | -- |
| BMI ($kg \cdot m^{-2}$) | Obese[1] | | 0.6 (0.4) | | | | 0.6 (0.4) |
| | Overweight[2] | | 0.4 (0.3) | | | | 0.4 (0.3) |
| | Normal | -- | -- | -- | -- | -- | -- |
| Moderate PA (min/day) | > 60 | | | -0.01 (0.3) | | | 0.04 (0.3) |
| | 30-60 | | | 0.2 (0.3) | | | 0.3 (0.3) |
| | < 30 | -- | -- | -- | -- | -- | -- |
| Vigorous PA (min/day) | > 15 | | | -0.1 (0.3) | | | 0.1 (0.3) |
| | 1-15 | | | -0.5 (0.4) | | | -0.4(0.4) |
| | 0 | -- | -- | -- | -- | -- | -- |
| Relative $VO_{2max}$ (ml/kg/min) | | | | | -0.02 (0.01) | | -0.02 (0.01) |
| Smoking | Yes | | | | | 0.2 (0.4) | |
| | No | -- | -- | -- | -- | -- | -- |

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ compared to reference category

[1] Obese: BMI ≥ 30.0 for Euro/Other; ≥ 32.0 for Māori and Pacific

[2] Overweight: BMI = 25.0–29.9 for Euro/Other; = 26.0–31.9 for Māori and Pacific

# CHAPTER 5

# DISCUSSION AND CONCLUSIONS

This chapter is a detailed discussion around this study's findings and the implications to the New Zealand (NZ) population and physical activity (PA) research on an international level. First, validity of the short and long NZ physical activity questionnaires (NZPAQ-SF and NZPAQ-LF, respectively) and the creation of a NZ-specific compendium of PA intensities are discussed, including first-time investigations into traditional activities performed by the NZ Māori population. Next, individual and weekday vs. weekend variation in PA, correlates of cardiorespiratory fitness (CRF) and the associations between PA and CRF to cardiovascular (CV) risk factors, which were found in this study's sample, are addressed. Lastly, limitations associated with the entire study are acknowledged and explained.

## 5.1 VALIDATION OF NZPAQS

Validity coefficients for physical activity questionnaires (PAQs) typically range from 0.2-0.4,[16,47] and PAQs with moderate correlations of 0.3-0.5[164] are usually reported as 'reasonably valid'.[29] Validity coefficients from this study are comparable to previous PAQ validity studies using heart rate monitoring (HRM) with individual calibration. Validation of the Sub-Saharan Africa Activity Questionnaire (SSAAQ) reported unusually strong correlations between 24-hour HRM and past-year walking and occupational PAs (0.50-0.62 and 0.44-0.72, $p<0.05$, respectively), although HRM was primarily conducted on participants living in rural areas (n=54), as only 6 of 35 urban participants underwent HRM, which was not individually calibrated.[67] However, the SSAAQ was designed with Sub-Saharan Africa's socio-cultural and economic background in mind. A higher proportion of rural participants engaged in high-intensity occupational PAs and brisk walking, compared to urban participants, and higher-intensity PAs tend to correlate more strongly on PAQs due to the higher physiological demands associated with these activities. Results from this study support that notion, as validity coefficients for brisk walking and vigorous-intensity PA on the NZPAQ-LF (0.4, $p<0.0001$) were stronger compared to moderate-intensity and total PA. Still, total PA reported for the last 7 days on both NZPAQs showed significant, moderate correlations to HRM ($r=0.3$, $p<0.001$).

Wareham et al.[44] validated the EPIC-Norfolk PAQ against 4 days of HRM with individual calibration in 173 participants. Mean weekly energy expenditure (EE) values reported during recreational (0.13) and occupational PAs (0.17, $p<0.05$) correlated poorly with HRM. Similarly, mean weekly EE assessed in this study by HRM and reported on the NZPAQ-SF (0.25, $p<0.001$) and NZPAQ-LF (0.22, $p<0.01$) (Analysis 4) were poorly correlated.

Method of Analyses

The purpose of the different analyses was to determine which method most closely reflected PA levels captured during the 3-day HRM period. Each technique has advantages and disadvantages.

Analysis 1 is the only method without assumptions, and would be the preferred method of analysis if the emphasis of PA surveillance was focused strictly on the amount of time spent in activities of at least moderate-intensity. The poorest correlations between the NZPAQ-SF (p=0.18, p=0.01) and the NZPAQ-LF (0.19, p=0.01) to HRM were reported by Analysis 1. In addition to the duration of activity, Analyses 2, 3, and 4 put additional emphasis on the intensity at which the PAs are performed. However, assumptions are associated with each method. Analysis 2 assumes 1 minute of vigorous-intensity activity is equivalent to 2 minutes of moderate-intensity activity, and both NZPAQ-SF and NZPAQ-LF had a correlation of 0.25 to HRM (p=0.0008 and p=0.0009, respectively). Analysis 3 is not recommended at this stage, as this method of analysis was specifically designed for a different questionnaire. The disadvantage associated with Analysis 4 is that individual body weight is required to calculate EE. Incorporating self-reported body weight into the questionnaires would introduce a great amount of error, and measuring body weight for each respondent may not be feasible. However, given the increasing rates of obesity in NZ, assessing PA in terms of EE may be a viable method of analysis for specific populations.

### 5.1.1 Physical Activity Measured by Heart Rate Monitoring

Total PA levels were calculated by summing HR data for time spent in brisk walking, moderate- and vigorous-intensity activity. It could be argued that PA levels were either consciously or subconsciously increased due to awareness that this behaviour was being monitored. However, in regard to PAQ validation, it was not a concern if habitual PA levels were altered. However, this would have an impact on the calculated proportion of participants meeting current PA recommendations. Although the 3-day HRM was converted to a 7-day total, PA levels from this study are consistent with literature on demographic comparisons of PA levels, which states that older adults, females, and ethnic minorities generally spend less time participating in moderate- and vigorous-intensity PAs, and are therefore more likely to be inactive.[3,167,168] In this study, participants who were aged 60+ yrs, Māori and Pacific, and females had lower total PA levels, compared to their younger, European/Other, and male counterparts.

Proportion of Study Sample Meeting Physical Activity Recommendations

Recommendations for PA levels have been provided since the late 1940's,[3] and were based primarily on maintenance and improvement of CRF.[3,169,170] Throughout the years, PA recommendations have been modified towards public health concerns, highlighting the health benefits associated with PA,[169,170] especially the growing public health concerns of obesity.[101]

Today, PA recommendations, in both the United States (US) and NZ, advocate 30 minutes or more of at least moderate-intensity PA on most, preferably all, days of the week, and that spreading PA over 5 days of the week maximizes health benefits.[3,6] Table 68 shows the proportions of this study's sample classified by different PA categories, both by HRM and on the NZPAQ-LF, compared to the 1998 New Zealand Sport and Physical Activity Survey (NZSPAS).[105] HRM data from this study showed substantially higher and lower proportions of 'relatively inactive' and 'highly active' participants, respectively, compared to self-reported data from the NZPAQ-LF and the NZSPAS. However, the proportion of 'relatively active' individuals captured by HRM (~21%) and reported on the NZPAQ-LF (~21%) and the NZSPAS (16%) were more similar. Table 68 also shows the proportion of participants who met current PA guidelines, in terms of total duration (150 min/week) and the combination of duration and frequency (150 min/week at least 5 days/week), of at least moderate-intensity PA in the last 7 days, measured objectively by HRM. The proportions of the samples who met current NZ guidelines in terms of duration were within ±10% of each other, and when PA recommendations were analysed by duration and frequency, this value decreased in both studies. However, the magnitude of decrease was substantially greater in this study compared to the NZSPAS, and is consistent in all age, ethnic, and gender groups (Appendix B1-4, pg.275). Findings from this study imply that PA-related health gains are not being maximized in the NZ population by spreading PA over 5 days of the week.

**Table 68.** Comparison of 7-day Physical Activity Levels: HRM vs. NZPAQ-LF and previous New Zealand Sport and Physical Activity Survey

| Activity Category | HRM (%) | 2002 NZPAQ-LF (%) | 1998 NZSPAS[105] (%) |
|---|---|---|---|
| Relatively Inactive: < 2.5 hours | 59 | 25 | 22 |
| Relatively Active: 2.5 to 5 hours | ~21 | 21 | 16 |
| Highly Active: ≥ 5 hours | ~21 | 54 | 52 |
| **Current NZ Guidelines[6]** | | | |
| ≥ 30 min/day on ≥ 5 days | ~5 | 20 | 39 |
| ≥ 150 min/week, < 5 days | ~34 | 33 | 42 |

NZSPAS = New Zealand Sport and Physical Activity Survey

In regard to the proportion of populations meeting current PA recommendations, results from the 1998 NZSPAS, and HRM and NZPAQ-LF data from this validation study, were compared to international findings (Table 69).[3,44,101,102,105,168,169] However, such comparisons are difficult to make with confidence, as criteria for meeting PA guidelines, PA definitions and categories, assessment techniques, and analytic approaches differ between countries.[16,102,169] The World Health Organization (WHO) reported that 60% of the world's population is insufficiently active.[100] These studies show that approximately 20-50% of populations are meeting the PA guidelines established by researchers in corresponding countries. Proportions of adult New Zealanders who are meeting current PA guidelines, assessed by HRM data (41%), fall within the expected range. However, self-reported PA levels from the NZPAQ-LF (75%) and NZSPAS (68%) are the highest proportions of populations meeting current PA guidelines. This highlights the substantial over-reporting of PAs in this population, and demonstrates the need for PAQ refinement, so that PA-related terms and concepts typically found on PAQs will be better comprehended by the people of NZ. Alternatively, exposing such terms and concepts through PA promotions would assist in educating the NZ people about PA, and possibly facilitate the administration of PAQs and increase accuracy of self-reported PA levels.

**Table 69.** International Comparisons of Sufficiently Active Populations

| Meeting Current PA Guidelines | Inactive (%) | Active (%) |
|---|---|---|
| Australia – 1996[102] | 50 | 50 |
| Canada – 1990[169] | 52 | 48 |
| England – 1992[169] | 55 | 45 |
| Finland – 1994[169] | ~70 | ~30 |
| New Zealand – 1998[105] | 32 | 68 |
| New Zealand - 2002 (HRM) | 59 | 41 |
| New Zealand - 2002 (PAQ) | 25 | 75 |
| United Kingdom – 2002[102] | 59 | 41 |
| United States – 2000[168] | 68 | 32 |
| United States – 2001[101] | 78 | 22 |
| Sweden – 1993[169] | 82 | 18 |

*HRM = Heart Rate Monitoring, PAQ = Physical Activity Questionnaire

### 5.1.2 Self-Reported Levels of Physical Activity

In general, self-reported duration of PA was considerably and consistently overestimated on both NZPAQs, by all age, gender, and ethnic subgroups. Previous PAQ validation studies have reported overestimates ranging from 100-300%.[115] In this study, total PA was over-estimated by as much as 85% for both New Zealand physical activity questionnaires (NZPAQs), but greater over-estimation occurred on the NZPAQ-SF.

Individuals with high levels of body mass index (BMI) or body fatness,[171,172] or are sedentary or unfit,[115] tend to overestimate PA, and data from the present study are consistent with these findings. Mean BMI (33.2 $kg \cdot m^{-2}$) was significantly higher, and relative maximum oxygen consumption ($VO_{2max}$) (24.5 $ml \cdot kg^{-1} \cdot min^{-1}$) was significantly lower in Pacific participants, compared to

European/Other participants (26.0 kg·m$^{-2}$ and 32.1 ml·kg$^{-1}$·min$^{-1}$), respectively. However, the extreme overestimation of PA duration may be linked to social desirability bias, which explains the tendency to present oneself in an overly-positive light.[172,173]

Physical Activity Intensity

The overestimation of PA duration by participants in this study was predominantly influenced by over-reporting of moderate-intensity activity, which showed no significant correlation to HRM. The entire sample, as well all subgroups, demonstrated poor recall of time spent in moderate-intensity activity on both NZPAQs, with the exception of European/Others. Duncan et al.[115] also reported poor recall of moderate-intensity PA by self-report, compared to HRM, as low- to moderate-intensity PAs are not recalled as accurately as vigorous-intensity PAs.[36,42,47,53] Furthermore, participants have difficulty distinguishing between light- and moderate-intensity PAs.[28,29] However, brisk walking, typically performed at moderate-intensity, showed significant moderate correlations on both NZPAQs. Brisk walking is a specific activity that many individuals perform routinely for exercise, and may be easier to identify and recall accurately,[43] although others have not concluded this.[43,116]

The absence of a significant relationship between self-reported and objectively measured moderate-intensity PA may suggest poor interpretation of the term "moderate-intensity", defined as activity that will cause a slight, but noticeable increase in breathing and heart rate (HR). Participants may have mistakenly reported light-intensity activities as moderate-intensity activity, as the distinction between these terms are often difficult to comprehend.[28] In this sample, participants who engaged in at least 14 min/day of moderate-intensity PA displayed better recall ability, compared to their less active counterparts. Recalling PA intensity is more difficult for less fit individuals, as they are unaccustomed to regular physical exertion,[42] and cultural differences associated with interpreting and comprehending the term 'moderate-intensity' could also have contributed to the low correlations between HRM and moderate-intensity PA.

In this study, the concept of vigorous-intensity was better comprehended than moderate-intensity. A review of seven validated, self-report PA instruments for young to middle-aged adults reported higher validity coefficients for vigorous-intensity activity, compared to moderate-intensity activity.[42] Correlations between actual vs. reported vigorous-intensity activity were substantially and consistently stronger for the entire sample and each ethnic, age, and gender subgroup, compared to moderate-intensity PA, especially by individuals who engaged in 18+ min/day of vigorous-intensity PA.

Subgroup analyses found that European/Others and males demonstrated better recall of vigorous-intensity activity, while recall among the three age subgroups were nearly identical. The significant physiological demands associated with vigorous-intensity activities could explain the higher correlations compared to moderate-intensity PA, as higher intensity activities are associated with greater participant recall.[36,50]

Subgroup Analyses

The 60+ yrs age group dramatically overestimated total activity compared to the 18-39 yrs and 40-59 yrs age groups. Older adults typically engage in less PA compared to younger individual.[2,3,167,168] In this study, despite having the lowest levels of objectively measured PA, older adults reported the highest average amount of PA on the NZPAQ-SF. Irwin et al.[172] reported a similar finding, with a 16.7% overestimation of EE in men 50+ yrs, compared to a 5.3% overestimation from men less than 40 yrs. Additionally, a study by Booth et al.[147] found lower correlations between self-reported EE and physical work capacity (PWC) in adults aged 50+ yrs, compared to younger individuals.

Between ethnic groups, the magnitude of PA overestimation was most extreme in Pacific participants. Warnecke et al.[173] evaluated the wording of survey questions in an ethnically diverse population and concluded that interpretation of PA questions was influenced by gender and ethnicity. While the influence of ethnicity was observed in this study, the influence of gender was not apparent. It is recommended to use ethnically-matched interviewers who administer PAQs in a way to minimise the effects of questions that could produce redundant information or cause the respondent to feel threatened.[173]

Physical Activity Contexts

Approximately 14% of activity bouts captured during HRM were coded as ‘Unknown’ activity, where participants were unable to report an activity mode for the elevated HR response. In this sample, self-reported duration of brisk walking by older adults and females was more strongly correlated to HRM on NZPAQ-LF (0.45 and 0.46, respectively), compared to the NZPAQ-SF (0.29 and 0.26, respectively). This suggests that the NZPAQ-LF may be a more valid assessment of activity for these individuals. Brisk walking is a specific activity that many individuals perform routinely for exercise, and may be easier to identify and recall accurately,[43] although others have not concluded this.[116]

One of the main goals of the NZPAQ-LF is to collect detailed information on the type, duration, and intensity of PAs performed in all contexts (sport and recreation, occupation, transportation, and incidental/other which includes household and lawn/garden activity). Measuring PA performed in all possible contexts has the potential of increasing measurement error, but also has the potential to decrease measurement error and provide better representation of total PA levels.

A strong correlation existed between activities (all contexts) reported on the PA Logs and recalled on the NZPAQ-LF. In general, accurately recalled activities took place at activity-specific locations (i.e. gym, basketball/tennis/volleyball court, golf course, rugby/soccer field), which required travel time, and therefore may explain the participants' ability to accurately recall these activities. The majority of poorly recalled activities occurred in the context of Incidental/Other, and are heterogeneous activities typically performed at home or unpredictable locations, which do not require a purposeful effort associated with transportation or travel time. Household activities and chores were frequently reported as moderate-intensity PAs, although this was rarely supported by the HRM data. Lawns and gardens come in different sizes, and these types of PAs are also difficult to measure accurately, as the time and effort involved with such activities varies substantially between individuals and countries.[8]

The assessment of occupational activity and classification of intensities is difficult due to daily and seasonal variation within occupations.[66] Furthermore, selection bias may exist as less active individuals select less strenuous jobs.[66,174] Although the Compendium[24] provides mean metabolic equivalents (METs) for specific PAs, individual performance of activities vary between mechanical efficiency and intensity.[8] The frequency of reporting occupational activities during HRM was low, therefore limiting the value of the intensity comparisons. In developed countries such as NZ, only a few occupations require high rates of EE. However, exclusion of the occupational context of PA from questionnaires would dramatically underestimate PA levels in individuals who regularly perform manual labour on the job.[8] This continues to be a challenging objective for physical activity research.

This study supports the notion that a single instrument is incapable of accurately quantifying PA levels, and that a combination of methods is most likely to produce better estimates. Surveillance of PA is an still in a stage of relative infancy, as there is plenty of room for advancements in technology and instrument refinement. However, until another valid, affordable, population PA measure is introduced, the NZPAQs are acceptable instruments for assessing PA levels in the NZ population, as validity coefficients are comparable to other PAQs validated by HRM. Additionally, the availability of NZ-specific METs should increase the accuracy of EE estimates and self-reported PA intensities in this population.

### 5.1.3 Comparison of Physical Activity Questionnaires

PAQ comparisons 2-5 presented on page 102 are discussed below. These include NZPAQ-SF vs. NZPAQ-LF, both NZPAQs vs. the NZSPAS, the NZPAQs vs. the international instrument (IPAQ-Long), and the IPAQ-Long vs. HRM.

NZPAQ-SF vs. NZPAQ-LF

This was the first validation study of, and comparison between, the NZPAQ-SF and NZPAQ-LF. The NZPAQ-LF more accurately reflected HRM data for total time spent walking briskly, and appears to be the better instrument for each age, ethnic, and gender group using Analyses 1, 2 and 4, although both NZPAQs were significantly and strongly correlated for this PA component. The superiority of the NZPAQ-LF over the NZPAQ-SF is most likely due to the day-by-day format of the Main PA Table, which collects very detailed information over the last 7 days, while the NZPAQ-SF is an abbreviated, more general questionnaire comprised of only 8 questions. The NZPAQ-SF uses 1 question to determine time spent walking in all contexts (sport/recreation, transportation, occupation, incidental), whereas the NZPAQ-LF specifically probes at walking for the purpose of sport/recreation and transportation. Self-reported time spent walking and total activity was greater on the NZPAQ-SF, indicating that the detailed responses required by the NZPAQ-LF may enhance participant recall by forcing participants to carefully think about each specific day. Correlations between the NZPAQ-SF and NZPAQ-LF were also strong for vigorous-intensity and total PA. The poor correlation for moderate-intensity PA may be due to a lack of comprehension of the term “moderate-intensity.”

NZPAQ-SF and NZPAQ-LF vs. NZSPAS

An adjustment factor was calculated to determine the conversion of the previous NZSPAS data to values collected on the NZPAQ-SF and NZPAQ-LF (Table 28). More specifically, total PA and the proportion of participants who meet current PA guidelines, calculated by each instrument, were compared. The NZSPAS assessed the duration of light-, moderate-, and vigorous-intensity PAs performed in the context of sport and recreation over the last 7 days, while the NZPAQs assessed only moderate- and vigorous- intensity PAs in all contexts (sport and recreation, transportation, occupation, and incidental/other). Kriska[49] concluded that the assessment of sports and leisure activities alone would most likely miss a significant portion of activities that comprise the total EE of certain subgroups. Consequently, it would be reasonable to expect a decrease in total PA duration when light-intensity activities are excluded, but this decrease would be compensated by an increase in PA captured in the additional PA contexts. Therefore, the NZPAQs would theoretically provide more accurate reflections of PA in the last 7 days.

As expected, the NZSPAS underestimated time spent in sport and recreational PAs, as adjustment factors ranged from 1.08-2.50 and 1.16-1.85 on the NZPAQ-SF and NZPAQ-LF, respectively, and the discrepancies were greatest for 40-59 yrs and Pacific participants. The application of adjustment factors is not recommended, as the values vary between subgroup and may be different in different samples.

<u>NZPAQ-SF and NZPAQ-LF vs. IPAQ-long</u>

The NZPAQ-SF and NZPAQ-LF were compared to the IPAQ-long to assess comparability with an international survey. Both NZPAQs were significantly correlated with the IPAQ-long for all activity components, suggesting that the NZ instruments provide a valuable estimate of PA. However, the IPAQ-long values were at least 1.5 times greater than those reported on the NZPAQs, with the majority of participants (76%) classified as "highly active", compared to the NZPAQ-SF (37%) and NZPAQ-LF (31%) (Analysis 3), indicating that the latter instruments are more accurate for the NZ population. It is interesting to note that the IPAQ-long was administered at Visit 2, immediately following HRM. It would seem logical that PA reported at this time would be more accurate compared to the NZPAQs, which were administered days later at Visit 3. However, the substantially higher PA levels reported on the IPAQ-long could be attributed to the fact that many specific PAs in every context are addressed, therefore allowing respondents the opportunity to report higher PA levels. An international study of the reliability and validity of IPAQ questionnaires stated that the IPAQ-long appears to produce higher estimates of PA than an abbreviated version, the IPAQ-short,[151] and this study supports that finding.

<u>IPAQ-long vs. HRM</u>

Short and long forms of the IPAQ were previously validated in 12 countries against accelerometers, which showed correlations of approximately 0.30.[151] This study administered the IPAQ-long version which was self-administered and assessed PA over the last 7 days (L7S). This same version was validated at 6 different centres in 5 countries (United Kingdom, United States, Finland, Sweden, and the Netherlands). Mean Spearman correlations for total PA, and agreement for participants engaging in > 150 min/week of PA were 0.32 and 78%, respectively.

In this study, total PA between the IPAQ-long and HRM were 0.07 ($p=0.37$) (Analysis 2), and activity categories showed poor agreement, with weighted kappa (κ) values ranging from 0.02 (Analysis 1) to 0.06 (Analysis 2) (Tables 33-36). Results from this study were mostly similar to those from one testing centre (San Diego, California, US), which reported a correlation of 0.05 for total PA, and agreement of 26% for > 150 min/week of PA. This study found self-reported PA levels from the IPAQ-long to be consistently and substantially higher than HRM data in the NZ sample, and although correlations were statistically significant for brisk walking (0.15-0.18, $p<0.05$) and vigorous-intensity PA (0.23-0.25, $p<0.01$), they were classified as 'poor'. Possible explanations for the considerable overestimation of PA levels on the IPAQ-long are provided on the previous page.

## 5.2 NEW ZEALAND COMPENDIUM OF PHYSICAL ACTIVITIES

This study is the first to report population-specific data on metabolic equivalents (METs) for PAs performed by New Zealand adults, and is advantageous in that age- and gender-specific MET values for a range of PAs are included (Tables 48-55). The energy cost associated with an activity can vary substantially within and between individuals, depending on influencing factors such as the person's age, sex, body mass, movement patterns, skill and level of fatigue.[29,95] Most published tables of energy costs have been limited by the study sample, either in terms of numbers, exclusion of one sex, or a narrow range of ages.[119] Additionally, there is a tendency to overestimate PA intensity in middle-aged and older adults, as tables of energy costs are usually based on data for young adults.[175] In this study, energy costs of PAs were objectively measured by HRM. Individual calibration processes determined relationships between HR and oxygen consumption ($VO_2$), which were used to convert mean HR values into METs, an intensity of metabolic activity relative to resting conditions.[29] The equation used in this study to predict $VO2_{max}$[162] from individual calibration yielded a mean difference of -0.32 ml·kg·min$^{-1}$ (-1.1%), compared to measured values, whereas Strath et al.[27] reported a deviation of ±15% between predicted $VO_{2max}$ values and those measured by calorimetry in 61 subjects. This suggests a high level of accuracy for NZ-derived MET values.

The US Compendium of Physical Activities[24] is an internationally-accepted list of MET levels for very specific PAs, but also lists METs for 'general' activities, which were used whenever possible to compare mean METs derived from this study's participants. If a corresponding PA was not listed in the US instrument, an average MET level was calculated from the most closely matched listings. Generally, METs from this study sample showed good correlation ($R^2$=0.62) to those listed in the US Compendium. The mean age of participants in this study (48.6 yrs) is not comparable to the US Compendium, as the latter is a compilation of findings from several published and unpublished studies.

### 5.2.1 New Zealand Māori Physical Activities

This study is the first to report MET values for traditional Māori activities (Table 56). Although the sample of Māori participants engaging in regular kapahaka practice was relatively small, these results provide baseline measures for 12 culturally-specific PAs. Intensity and rate of EE for these PAs varied within and between individuals for several reasons. For example, some individuals are more familiar with the different activities, and perform them at the intended level of intensity, while newer members tended to stay in the back and focus on learning proper execution of the PAs. Additionally, each individual's level of motivation to perform the activities at a competitive level was a factor. Although males and females perform many of the same activities, the EE of each gender's role should be kept separate, as the male and female activities are generally performed at vigorous and moderate intensities, respectively. Similarly, MET levels are consistently higher for the 18-39 yrs age group compared to the 40-59 yrs age group. Finally, Te Roopu Manutaki holds kapahaka practices year-round, and the intensity of these PAs will surely increase as competition nears and individuals are chosen to represent their kapahaka group. Future studies should endeavour to assess these activities in greater numbers.

## 5.3 INDIVIDUAL VARIATION IN PHYSICAL ACTIVITY

### 5.3.1 Daily Variation

Individual variation of time spent in at least moderate-intensity PA was examined in 121 adult participants over a 3-day HRM period (Table 19). Within-person variation was calculated at 32.2 min/day (16.7%). The least and greatest amount of variation was seen in the 18-39 yrs (23.4 min/day) and 40-59 yrs (41.2 min/day) age groups. Within-person variation for time spent in PA was reported at 55-57% for a sample for a sample of 92 individuals aged 18-79 yrs,[143] although that study used accelerometers to objectively measure PA over a 3-week period.

### 5.3.2 Weekday vs. Weekend Variation

The two studies reviewed in section 2.6.2 reported conflicting results in regard to weekday vs. weekend PA levels Matthews et al.[143] reported an average of 30-45 minutes more PA during the week compared to weekends (N=92), while Wareham et al.[60] found no significant weekday vs. weekend differences (N=97).

In this study, the research team made a conscious effort to capture at least one weekend day of HRM when the participant's schedule permitted. A total of 121 participants from this study had both weekday and weekend HRM data. Although participants were instructed to maintain normal PA habits during HRM, some were purposefully more active. On the other hand, some participants were less active than usual during HRM, due to illness or unexpected events. It was therefore assumed that participants who were atypically more and less active balanced each other out. Although the difference was small, total weekend PA performed in each context was 9% greater compared to total weekday PA (Section 4.1.1). Lack of time and having no exercise partner or facility available, are the primary barriers to participation in PAs during both men's and women's leisure time.[167] It seems logical that individuals have more spare time during the weekends, and therefore more time to spend on incidental PAs in and around the home, or sport and recreational PAs during leisure-time. However, there are several factors associated with adult participation in PA (i.e. social and cultural, personal, environmental, psychological, and behavioural), which require further investigation through longitudinal and intervention studies[167] to promote positive lifestyle changes through PA in high-risk populations in NZ.

## 5.4 CORRELATES OF CARDIORESPIRATORY FITNESS

A multiple linear regression analysis was performed to investigate the determining factors associated with CRF levels (Table 21). The age group variable was excluded from the models since age-predicted $HR_{max}$ (220 – age) was used to predict $VO_{2max}$.

### 5.4.1 Variables Related to Cardiorespiratory Fitness

Gender and Ethnicity

The base model, including gender and ethnicity, showed these variables to be significant correlates of $VO_{2max}$. It is not surprising that males demonstrate significantly higher $VO_{2max}$ levels compared to females, as this has been shown in previous international studies.[3,168,176] Despite the significant role that CRF plays in relation to performance and cardiovascular disease (CVD), population-specific $VO_{2max}$ norms are scarce.[176] This study offers baseline data supporting the existence of ethnic differences in CRF levels in NZ.

In the US, Asian and Pacific Island (API) populations are generally combined for statistical purposes, and Ayers et al.[177] reported API $VO_{2max}$ levels to be lower than non-minorities but higher than African-Americans. Ethnic comparisons of $VO_{2max}$ levels do not appear to have been reported for other populations. Collectively, Māori and Pacific people in NZ are referred to as Polynesians.[92,178-181]. This study found ethnicity to be an important variable related to $VO_{2max}$, as estimates for European/Other were significantly higher than Māori ($p<0.05$) and Pacific ($p<0.001$) participants. An unpublished NZ study[182] conducted on a multi-ethnic sample of adolescents (N=2,549) aged 14-21 yrs found similar ethnic trends in CRF levels. Schaaf et al.[182] assessed aerobic power through measures of physical work capacity (PWC). After adjusting for age, gender and cluster sampling, significant ethnic differences were found, with European adolescents displaying the highest mean PWC values, followed by Māori, Asian, and Pacific adolescents (Table 70). The comparatively low CRF levels reported for Pacific people in both NZ studies implies CRF is an inherently important CV risk factor contributing to the health status of this already established high-risk group. Furthermore, it can be inferred that low CRF seen in Pacific adolescents is carried into adulthood. The aggregated API data leads one to infer that Pacific people in the US are a healthy model minority,[183] while the Polynesian group is recognised as a high-risk population in NZ,[178-180,184-186] and other parts of the Asia-Pacific region.[108,181] The health disparities between NZ Polynesians and Europeans are discussed further in Section 5.4.2.

**Table 70.** Ethnic differences in adolescent levels of Physical Work Capacity (N=2,487), adjusted for Age and Gender

| Ethnicity | N | Mean PWC in Watts·kg$^{-1}$ (SE) [182] |
|---|---|---|
| European | 597 | 2.31 (0.03) |
| Māori | 332 | 2.16 (0.04) |
| Asian | 533 | 2.07 (0.06) |
| Pacific | 1,025 | 1.99 (0.04) |

PWC = Physical Work Capacity

Obesity

In addition to blood lipids and BP, CRF levels are inversely related to body weight and body fat.[79] In this sample, European/Other, Māori and Pacific participants were classified as normal weight, overweight and obese, respectively, and demonstrated the highest, intermediate, and lowest levels of CRF, respectively. No significant ethnic differences existed for height measurements, although Polynesian participants were significantly heavier ($p<0.0001$) than European/Others, resulting in significantly higher BMI values ($p<0.0001$). Obesity, classified by BMI levels ≥30.0 and ≥32.0 kg·m$^{-2}$ for European/Others and Polynesians, respectively, was also found to be a significant determinant of $VO_{2max}$ ($p<0.001$). When BMI values were added to the base model, mean ethnic differences in $VO_{2max}$ decreased, resulting in a nonsignificant difference between European/Other and Māori. Although mean difference between European/Other and Pacific participants remained significant, the level of significance decreased from $p<0.001$ to $p<0.05$. These findings indicate that ethnic differences associated with $VO_{2max}$ levels are related primarily to obesity.

Physical Activity

Although CRF and PA are closely related, $VO_{2max}$ is not a direct measure of PA and is therefore an inadequate validation technique for PAQs.[36] PA is a modifiable, lifestyle risk factor which has a direct impact on CRF.[72,82,87] However, studies which have used CRF to validate PAQs have found higher correlations between vigorous-intensity PA (0.48-0.55), compared to light- and moderate-intensity PA (0.02 and 0.13, respectively), as the physiological stress associated with higher intensity PAs are more readily and reliably recalled on PAQs.[36,77,147] Data from this study supports this notion, as participation in vigorous-intensity PA for >15min/day was associated with significantly higher $VO_{2max}$ levels compared to <15 min/day ($p<0.05$). Ethnic differences in $VO_{2max}$ decreased when adjusting for moderate- and vigorous-intensity PA, although only 18% of the variation around $VO_{2max}$ was explained by PA variables, suggesting a weaker association compared to BMI.

Final Linear Regression Model for $VO_{2max}$ Correlates

The inclusion of gender, ethnicity, BMI, moderate- and vigorous-intensity PA explained 23% of the variation in $VO_{2max}$. In this final model, mean differences for gender, ethnicity, BMI and vigorous-intensity PA decreased. However, obesity and gender differences remained significant, while ethnic differences decreased to nonsignificant levels. Vigorous-intensity PA, although significant ($p<0.05$) when added to the base model alone, became borderline significant ($p=0.05$) when included in the final regression model. In general, the final regression model shows partial confounding between BMI and PA, and confounding from these variables on ethnic differences associated with $VO_{2max}$. Individuals who regularly participate in vigorous-intensity PA can perform more physically demanding activities for longer time periods, thus resulting in higher $VO_{2max}$ levels. Furthermore, regular vigorous-intensity activity would result in lower BMI values due to the increased EE rates associated with higher-intensity PAs, and individuals with lower BMI values tend to be more fit. In 1992, participation in vigorous-intensity PA was reportedly lower in Pacific males (28%) and females (18%), compared to European males (33%) and females (30%) in NZ.[185] Data suggest this trend still exists, given the significantly lower CRF levels of Pacific people, compared to Europeans. However, promoting vigorous-intensity PA to sedentary populations would mostly likely be ineffective, as individuals unaccustomed to regular PA are unlikely to have the physical capacities required to perform PAs at high intensities.[170] Instead, given the health benefits associated with moderate-intensity PA advocating participant in moderate-intensity PA appears to be a more realistic approach.

### 5.4.2 Cardiorespiratory Fitness and Physical Activity vs. Cardiovascular Risk Factors

CVD is the leading cause of mortality in both developed and developing countries in the Asia-Pacific region, with NZ having the highest rates of CVD for both males and females.[1] Regular participation in vigorous-intensity PA is inversely related to obesity, and positively associated with CRF level.[36] Previous research shows that CRF is inversely related to blood cholesterol, triglycerides, glucose, BP and smoking,[75,79,80] and has a greater impact on CV health compared to PA.[72,75-77] In an effort to investigate and compare cardioprotective roles of PA and CRF in this sample, multiple linear regression analyses were performed for BMI, hypertension, and fasting blood lipids.

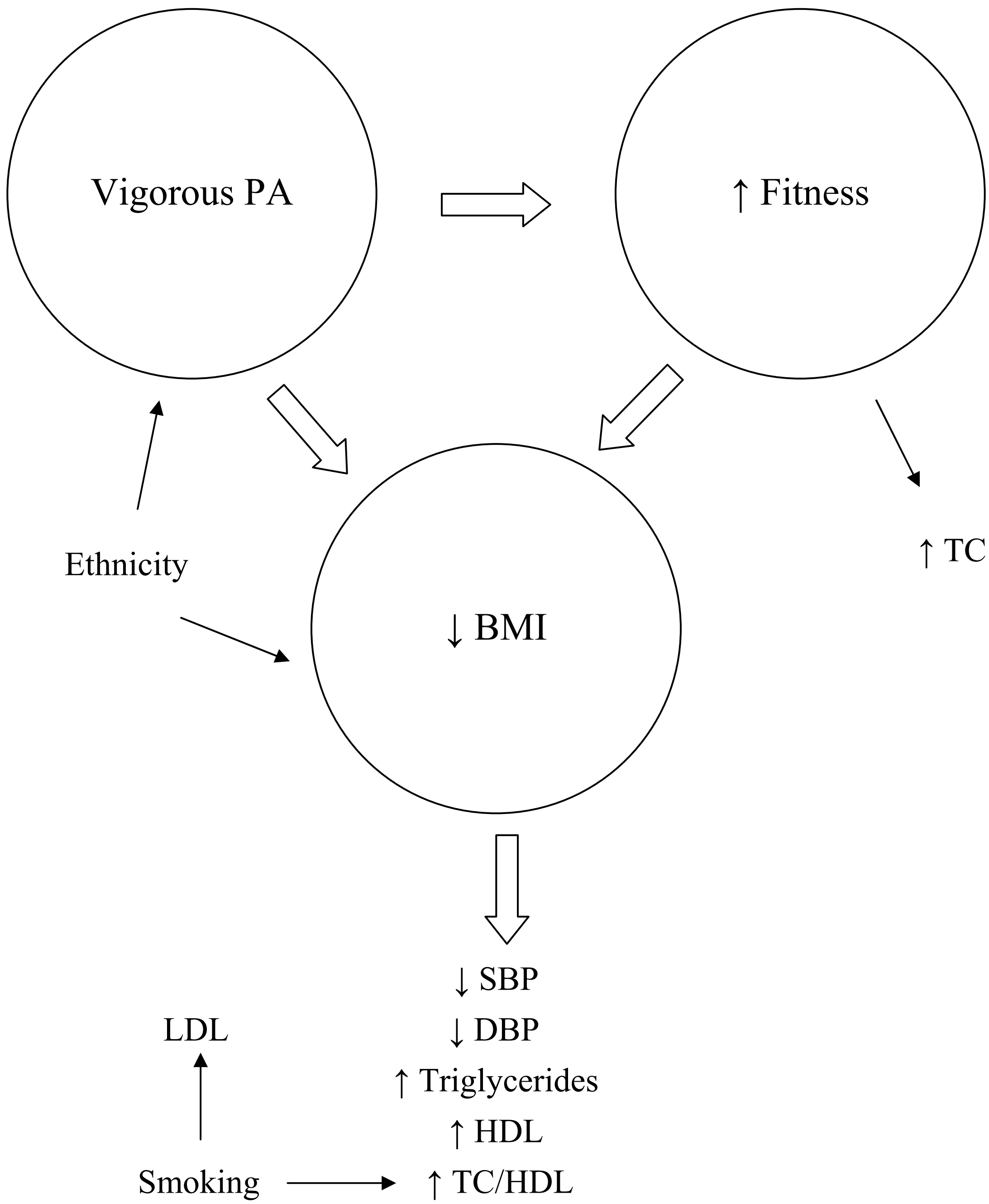
Overall results from this study's multiple linear regression models are diagrammed in Figure 15, which shows ethnic differences in obesity and PA levels, particularly vigorous-intensity PA, influence ethnic differences in CRF. Participants with higher CRF levels demonstrated lower BMI levels, which were associated with more positive blood lipid profiles compared to their less fit counterparts. This is a conceptual model that needs confirmation by path analysis or similar. Compared to PA, CRF was also more strongly related to BMI, triglycerides (TG), high-density lipoprotein (HDL)-cholesterol, low-density lipoprotein (LDL)-cholesterol, total cholesterol (TC), TC/HDL ratio, and fasting glucose, although statistical significance was observed only for BMI, TC, and TC/HDL-cholesterol, independent of PA (Tables 23-31). Moderate- and vigorous-intensity PA was more highly correlated to systolic blood pressure (SBP), compared to CRF. Blood lipid analyses were performed on 92 participants, as the blood test offered to participants in this study was optional. The samples with and without blood tests were significantly different in terms of ethnicity, PA level, and smoking habit (Table 58).

Ethnic Differences in Cardiovascular Risk Factors

Results from this study are consistent with previous reports that NZ Polynesians are substantially less active[185] and have greater rates of overweight and obesity,[92,178-180,185-189] compared to NZ Europeans. Furthermore, this trend in Polynesian BMI values is apparent in both adolescence[182,185,190] and adulthood[92,179,180,185,188,189,191] when compared to other populations.

Both SBP and diastolic blood pressure (DBP),[192] as well as blood lipids,[193] are associated with PA and EE, and Polynesians typically display higher levels of hypertension and blood lipids, compared to Europeans.[178,179,182,194] In this study, BP increased positively and negatively with BMI and CRF, respectively, and Pacific participants had significantly higher SBP and DBP compared to European/Other participants, while intermediate levels of BP and CRF were found in Māori. This study also found significant associations between BMI and TG, HDL-cholesterol and TC/HDL-cholesterol. Previous studies investigating the relationships between Polynesian BMI values and CV risk factors found associations with SBP, DBP, TC, HDL-cholesterol, TC/HDL-cholesterol ratio.[179,187] Schaaf et al.,[182] reported significantly higher levels of BMI, DBP, TG, TC, HDL-cholesterol, LDL-cholesterol, TC/HDL-cholesterol ratio, and fasting glucose in adolescent NZ Polynesians (although TC and LDL-cholesterol were not significantly higher in Pacific), compared to Europeans. Although this study's sample size was much smaller, results showed Polynesian HDL-cholesterol levels were significantly higher than European/Others, and the Pacific sample also showed higher levels of fasting glucose, a marker for Type 2 diabetes.[180]

**Figure 10.** Results of Multiple Linear Regression Analyses: Physical Activity and Cardiorespiratory Fitness vs. Cardiovascular Risk Factors



## 5.5 LIMITATIONS TO THIS STUDY

### 5.5.1 Sample Size, Selection, and Representativeness

Due to the invasiveness and burden associated with gold standard procedures, small, convenient samples are typically selected, and therefore caution should be used when extrapolating validation study results to other populations.[146] The respondent burden associated with this study's design was high. Three face-to-face visits were required from each participant, which entailed a physically demanding exercise test and administration of 4 different PAQs. Additionally, the 3-day period of HRM involved simultaneous completion of daily PA Logs, requiring participants' full cooperation and availability.

This study used non-random, convenience sampling in an effort to avoid low participation rates, and therefore may not be representative of the general population. Participants were recruited from several different community settings, as well as word-of-mouth, in an effort to ensure the sample would be representative of the Auckland population. Although this was not a pure cluster sampling frame, this type of sampling introduces design effect, which decreases standard error (SE) values, leading to falsely low p-values and an increased chance of false positives. Our sample size was relatively large, compared to other studies using the HRM technique to assess PA[27,62,63,69,126,129,131,133,149] or validate PAQs.[67,140] However, numbers for subgroup analyses were comparatively small, and may limit the validity of within-group associations, as well as the ability to detect interactions between subgroups, as the sample size required to detect interactions will have to be at least four times larger that the sample size required for detecting main effects of the same magnitude.[195] This study's sample consisted of volunteers interested in taking part in a health-related research study, or who had the desire to obtain a free CV risk profile or an individually tailored exercise prescription, and met the criteria for age, gender, and ethnic groups. These individuals were therefore more likely to maintain a higher level of compliance and commitment to the study.

This sample included a wide age range, the major ethnic groups in NZ, and both gender groups. The usual age, ethnic, and gender differences were observed in terms of BP and BMI, as older and Polynesian participants demonstrated increased CV risk from these variables. However, in terms of PA, overweight, or smoking habit, this sample may not be representative of the NZ population. Although European/Other and male participants had higher PA levels compared to non-European and female participants, which is consistent with previous literature on PA and demographics, the highest

PA levels occurred in the 40-59 yrs age group (Appendices B1-4, pg.275), but would have been expected in the 18-39 yrs age group.[196] However, the differences in PA levels by age group were not statistically significant. In relation to BMI, approximately 40% of males and 30% of females in NZ are classified as overweight, while 15% and 19%, respectively, are obese.[196] In this sample, male (40%) and female (30%) prevalences of being overweight matched previous findings, while male (38%) and female (42%) obesity in this sample was substantially higher. In 2002, 25% of individuals aged 15+ yrs in NZ smoked cigarettes, with the highest and lowest prevalence found in people aged 25-34 yrs and 55+ yrs, respectively.[197] The proportion of smokers in our study sample (21%) was similar to the population level reported previously, and our participants aged 60+ yrs had the lowest smoking rate compared to younger age groups. However, prevalence of smoking was similar between European/Others (20%), Māori (21%) and Pacific (22%), whereas higher values were expected for Māori (49%) and Pacific (35%).[197] These findings also support the earlier statement that the sample of 186 participants limits the power of subgroup comparisons. Significant differences were also observed between participants who opted to receive the free blood test, as the willing subsample was comprised mainly of non-Pacific, non-smoking, older participants. The representativeness of this subsample to the wider NZ population is therefore questionable.

### 5.5.2 Measurement Error

Flaws in the data collection procedures can result in errors in measurement or data records, leading to misclassification.[146,198] This study collected physical and physiological measures from participants, as well as self-reported data on PAQs. The nature of PAQs makes them prone to recall, social desirability, and interview bias. Recall bias occurs from participants attempting to report their PA modes, intensities, and durations over the last 7 days, and social desirability bias occurs when respondents report these values at socially acceptable levels. Interviewer bias can arise from attempts to clarify[146] or interpret[198] participant responses in a manner which deviates from standard protocol. Interpretation bias by participants was also a concern, as the PAQs introduced participants to many unfamiliar terms and concepts, and participants requiring language interpreters could have received different definitions or explanations. The above mentioned biases could have resulted in misclassification or overestimation of PA levels for a significant proportion of study participants, and ultimately affected the study's validity.[146,198] Differential misclassification, which may have resulted from recall bias, can strengthen or weaken associations, and the degree of misclassification is different between groups. Measurement error may have caused the same degree of misclassification between groups (non-differential misclassification), therefore weakening associations.

Although random misclassification is inevitable and occurs to some degree in nearly all types of epidemiologic studies,[198] steps were taken in this study to minimise such biases by designing very specific, standardised protocols for data collection at all three visits, including probing for clarification and dealing with "I don't know" responses on PAQs. Research personnel attended multiple training sessions and were provided with a detailed, written procedure manual describing the background, general study design and descriptions of exact protocols for data collection, coding, and recording during each visit. This also included background information and operational protocols for each measurement instrument. It was hoped that this would maximise the likelihood that tasks will be performed as uniformly as possible.

### 5.5.3 Confounding

Confounding refers to the complex interrelationships between variables and suggests that differences between groups, in variables other than what is being measured, are possible explanations for statistical associations, or lack thereof.[198] In this study, confounding variables would be associated with, but independent of, CRF (i.e. age, ethnicity, gender, smoking status, and obesity vary between individuals who are regularly active, and those who are not). Stratum-specific estimates were calculated for age (18-39 yrs, 40-59 yrs, 60+ yrs), ethnic (European/Other, Māori, Pacific), and gender (male, female) groups to control for and analyse confounding variables. Additionally, multiple linear regression analyses were also performed, which describe the interrelationships between variables while simultaneously controlling for several possible confounders.[146,198]

In this study sample, CRF levels were confounded by gender, ethnicity, obesity, and vigorous-intensity PA. Gender and obesity are not surprising confounders, as males generally have higher CRF levels than females, and obese individuals are not capable of physical exertion at the same intensity or duration than normal weight individuals. A minimum of 15 min/day of vigorous-intensity PA not only contributes to previous findings for the relationship between high-intensity PA and CRF, but also quantifies a threshold for this association. Ethnic comparisons of CRF levels offer new information to the literature, in that Pacific people had significantly lower levels of fitness, compared to NZ Europeans. Although PA and CRF were both confounders for CV risk factors, CRF showed stronger associations to BMI and blood lipids, while PA was more strongly associated with SBP and DBP.

### 5.5.4 Limitations to Validation of New Zealand Physical Activity Questionnaires

Possible explanations for the overestimation of PA on the NZPAQs are discussed below, including limitations associated with HRM, design, terminology, and methods of analyses for the NZPAQs.

Limitations of Heart Rate Monitoring

Section 2.5.2 discussed general limitations associated with the HRM technique for assessing free-living PA. This section discusses limitations to the HRM technique which were specific to this validation study. Exercise tests were terminated early for 3 males (mean age = 75 yrs) and 8 females (mean age = 67 yrs) who were unable to complete all three stages. However, these participants successfully completed the warm-up stage and reached steady-state HR. Average resting heart rate (RHR) and resting $VO_2$ values were used to calculate the slope and intercept of the HR vs. $VO_2$ relationship for these 11 participants. These values were required to determine MET values and EE of the activities captured during HRM.

The use of HR to estimate the intensity of an activity has several limitations. Although HR vs. $VO_2$ calibration curves are the most accurate method to estimate EE,[10] the relationship is affected by a person's age and fitness level, and is a questionable indicator of intensity during very low and very high-intensity activities.[23] Activities involving the upper body elicit higher HR responses compared to lower body exercises, and ideally, a calibration curve for upper body activities should also be conducted. Additionally, HRM data captured several episodes where HR was greater than 40% HRR for at least 10 minutes, but when questioned about activity during this timeframe, participants reported emotional and environmental stressors, such as being upset with a work colleague or stuck in traffic.

An ideal validation would consist of a 7-day HRM period. However, 3 days of HRM was chosen by the researchers as the maximum timeframe attainable without severely increasing respondent burden. HR monitors are quite complex, as they are designed for training serious athletes. Consequently, participants in HRM studies encounter difficulties operating the HR monitors.[115] In this study, participants received precise verbal and written instructions on starting and stopping HR recording, plus a courtesy phone call on Day 1 of HRM. Despite these efforts, HR data was not successfully recorded for several participants, and some, if not all, of the HRM period had to be repeated.

All HRM data required conversion to daily activity and then scaling to activity over the last 7 days to allow for comparison to the NZPAQ-SF and NZPAQ-LF. Most participants wore the HR monitor for part of the weekend, which helped capture any differences between weekday and weekend activity. Although wearing the monitor may have affected each participant's recall of PA, it was assumed that the 3-day HRM period was a typical reflection of PA levels, and that participants who were atypically inactive were counterbalanced by those where were atypically active.

Seasonal variation in the amount and type of PAs performed may have skewed results, as participants were interviewed predominantly by ethnic group. Generally, European/Other participants were interviewed from November to February, Māori from March to May and throughout July, and Pacific from May to June. Weekly activity was consistently greatest for the European/Others, followed by Māori and then Pacific. Literature pertaining to seasonal variation of PA levels in NZ was not available.

Participant Recall of Physical Activity

Self-report PAQs are ultimately limited by the respondent's ability and motivation to recall details of PAs.[6,66,115] In this study, participants were provided PA logs to complete during HRM, which could have affected activity levels,[6,25] and were limited by participants' ability to follow the verbal and written instructions provided.[42] The NZPAQ-SF and NZPAQ-LF were administered at least 2 days following HRM so that recall would not be influenced by completion of the PA logs.

Comprehension and Interpretation of Terms

The majority of participants had difficulties comprehending definitions provided on the NZPAQs and their associated showcards. Definitions of "moderate" and "vigorous" intensities were poorly comprehended and required several repetitions and further clarification for the majority of participants. The PAQ administers felt the definition of "vigorous-intensity" activity (makes you "huff and puff") was better understood compared to "moderate-intensity" activity ("cases a slight but noticeable increase in breathing and HR"), although both definitions caused confusion and may have contributed to over-reporting.

Definitions of "active" and "regular physical activity" were provided twice on the NZPAQ-SF (Questions 7 and 8) and once on the NZPAQ-LF (Stage of Behaviour Change). These questions required participants to report how many days of the last 7 days they participated in "15 minutes or more of vigorous activity (makes you ‘huff and puff’) or 30 minutes or more of moderate activity (caused a slight but noticeable increase in breathing and heart rate), including brisk walking”. Participants’ answer to this question represented the total days (frequency) of being active. Due to the inclusion of additional terms and definitions of moderate- and vigorous-intensity activities, respondents found these lengthy questions extremely confusing. These questions were poorly interpreted by the majority of participants and had to be repeated several times during the interview. The older age groups seemed to have even greater difficulty understanding the definition of “active”. Consequently, participants’ “regular physical activity” levels were most likely not represented accurately.

Comprehension difficulties were also encountered while distinguishing between walking in sport/recreation and transportation contexts on the Main PA Table of the NZPAQ-LF. Recreational walking was reported prior to walking for transportation. Participants were reminded that walking in the context of transportation was for the sole purpose of traveling from place to place, such as work, shops, a friend’s house, the bus stop, etc. When asked about transport PAs, some participants were inclined to re-report recreational walking because they passed a friend’s house or the bus stop during the course of their walk. It is possible that there was over-reporting for walking performed in either context. However, there may be under-reporting in the transportation context, especially in the 60+ age group, as these participants typically considered walking (in any context) as a form of exercise, and tended to disregard the subsequent question.

<u>Cultural/Ethnic Differences and Language Barriers</u>

Lack of comprehension was further exacerbated by language barriers. For example, 70% (n=21) of the 30 participants (1 Māori, 29 Tongan) who required an interpreter (Table 71) reported they were regularly physically active, meaning they engaged in a minimum of 75 minutes of vigorous-intensity activity, or 150 minutes of moderate-intensity activity for at least 5 of the last 7 days. However, HRM data for these 30 participants revealed average PA levels of 50.9 (95% CI = 16.2, 85.6) minutes over the last 7 days. Samoan and Tongan translations of the PAR-Q, PA Logs and NZPAQ-LF Showcards are located in Appendix A, pgs.259 and 266, respectively.

Terms and concepts typically associate with PAQs, such as “physical activity”, “moderate-intensity” and “leisure-time”, are unfamiliar to some cultural and ethnic groups, and may introduce interpretation bias.[42,49] For example, the concept of "leisure-time" has been associated with inactivity and laziness, or considered a luxury that many women do not have.[49]

Additionally, when a PAQ question was unclear, participants requiring interpreters provided extensive summaries of their PAs in a typical day, rather than a quantitative response to the specific question. This required the interpreter to engage in lengthy dialogue to pinpoint the response, which may have introduced bias. However, this occurred with many older Māori and Pacific participants who did not require an interpreter, implying that this behaviour may be due to a combination of age and cultural factors, rather than being a consequence of translation.

**Table 71.** Participants Requiring Language Interpreters

| | | **Participants Requiring a Language Interpreter** | |
|---|---|---|---|
| | **N** | **n** | **%** |
| Total Sample | 186 | 30 | 16.1 |
| **Age** | | | |
| 18-39 yrs | 64 | 1 | 1.6 |
| 40-59 yrs | 60 | 7 | 11.7 |
| 60+ yrs | 62 | 22 | 35.5 |
| **Ethnicity** | | | |
| European/Other | 60 | 0 | 0.0 |
| Māori | 61 | 1 | 1.6 |
| Pacific | 65 | 29 | 44.6 |
| **Gender** | | | |
| Male | 90 | 14 | 15.6 |
| Female | 96 | 16 | 16.7 |

Limitations to Analyses of New Zealand Physical Activity Questionnaires

Limitations were encountered while analysing the data by categorical variables. Frequency of activity (days per week) could not be directly determined from the IPAQ-long or NZPAQ-SF. The IPAQ-long records frequency for each context of activity, and further specifies frequency of both moderate- and vigorous-intensity PA within each context. Consequently, the total days reported for PA ranged from 0 to 77. For data analyses, it was assumed that individuals performed each type of PA on different days, and did not report any activity under two or more intensity categories. Therefore, the reported frequencies were simply summed, which may have resulted in overestimation of PA for some individuals. However, the occurrence of this error should be minimised as PAs are categorised by both frequency and duration.

There are limitations involved in Analysis 3, as this method of analysis was designed for the IPAQ-short, a questionnaire not administered in the present study. Recommended MET values for walking, moderate- , and vigorous-intensity activities were 3.3, 4.0, and 8.0 METS, respectively, which were derived from the IPAQ validity and reliability study undertaken in 2000-2001.[163]

The Main PA Table on the NZPAQ-LF could capture time spent in moderate- and vigorous-intensity walking for exercise or leisure (10-30min and >30min), transport, and occupation (activity codes 40, 41, 200, 303, respectively). However, walking at the gym was aggregated into activity code 12, a generally broad category that included "exercise classes/going to the gym/weight training" (Appendix A, pg.253). Consequently, any walking for exercise, sport or leisure that took place in a gym environment could not be included in the analysis comparing total time spent walking during the last 7 days. The author of this thesis recommended the inclusion of brisk walking for occupation in Q.1 of the NZPAQ-SF (Appendix A, pg.245), and suggested that activity code “12a - walking at the gym" be included in either the Sport and Physical Recreation Activities Showcard (Appendix A, pg.253), or in the interviewer instructions for administering the NZPAQ-LF (Appendix A, pg.256).

### 5.5.5 Recommendations for New Zealand Physical Activity Questionnaires

In November 2003, several recommendations were put forth to Sport and Recreation New Zealand (SPARC) in regard to facilitating administration of NZPAQ-SF and NZPAQ-LF, for both interviewers and respondents. The following recommendations were justified and have been accepted by SPARC.[28]

Physical Activity Definitions and Concepts

- The definition of "moderate-intensity" required clarification, given the promotion of at least moderate-intensity activity in the current PA recommendations. Any changes to this definition should be kept consistent throughout the questionnaires.

- The distinction between light- and moderate-intensity activities requires improvement in the form of definitions and/or physiological descriptions, as non-active individuals may not be familiar with breathing and HR descriptions often used to determine the intensity of an activity.

- Culturally-relevant examples of PAs should be provided, where applicable.

- A standard definition of "resistance training activities" should be created, including examples of different types of resistance (free weights, body weight, water, etc.) as well as the purpose for performing the activity (increase muscle size/strength/endurance, bone density, etc.)

Methods of Analyses

- Analysis 1 is advantageous in that there are no assumptions involved, and is adequate for surveillance of the duration of at least moderate-intensity activity.

- Analysis 2 emphasises the importance of participation in vigorous-intensity activity and is better correlated to HRM than Analysis 1. This is the preferred method of analysis if the purpose of surveillance is to determine total duration of activity, while acknowledging the importance of vigorous-intensity activity.

- Analysis 3 is not recommended at this stage, as this method of analysis was specifically designed for a different questionnaire.

- Analysis 4 is advantageous for determining EE at the individual level, while also acknowledging the importance of PA intensity. However, it is not a feasible method of analysis at the population level, as individual body weight measurements are required.

NZPAQ-SF

- The original NZPAQ-SF questionnaire was rearranged (with SPARC's approval) in an effort to prevent over-reporting of vigorous- and moderate-intensity activities. Participants were first asked about brisk walking, followed by moderate- and vigorous-intensity activities.

- ‘Frequency of Activity’ and ‘Stage of Behaviour Change’ heading were inserted above questions 7 and 8, respectively

- Participants found question 7 difficult to comprehend due to the wordiness and inclusion of definitions for both moderate- and vigorous-intensity activities. Compartmentalisation of question 7 was recommended using the following example:

    7. Thinking about all your activities over the last 7 days (including brisk walking), on how many days did you engage in:
        - At least 30 minutes of moderate activity that caused a slight but noticeable increase in breathing and heart rate, OR
        - At least 15 minutes of vigorous activity that made you ‘huff and puff’

## 5.6 CONCLUSIONS AND PUBLIC HEALTH IMPLICATIONS

Levels of CRF, represented as estimated $VO_{2max}$, were measured during the individual calibration procedure required for HRM, and were presented in relative terms ($ml \cdot kg^{-1} \cdot min^{-1}$) to allow for comparisons between individuals of different body sizes. As suspected, but unable to be confirmed by NZ literature, European/Other participants had significantly higher $VO_{2max}$ levels compared to Māori ($p=0.02$) and Pacific participants ($p=0.0002$). Multiple linear regression models identified that the observed ethnic differences in $VO_{2max}$ were strongly influenced BMI and participation in vigorous-intensity PA. Compared to PA, CRF demonstrated a stronger association with favourable fasting blood profiles (TG, TC, HDL-cholesterol, LDL-cholesterol, TC/HDL-cholesterol ratio, and fasting glucose), whereas vigorous-intensity PA was more strongly related to SBP and DBP. Levels of PA, CRF, and BMI are inter-related and Pacific participants in this sample were identified as the high-risk population in which to focus on promoting PA and CV health. Results from this portion of the research study signify the health benefits associated with higher levels of CRF. In addition to promoting participation in at least moderate-intensity PA for health benefits, increased awareness surrounding vigorous-intensity PA to increase CRF levels is also important.

The Physical Activity Joint Monitoring Group (PAJMG) in NZ developed two NZPAQs in hopes of increasing the accuracy of PA prevalence measures in adults. Validity coefficients for both NZPAQ-SF and NZPAQ-LF were typical of PAQ validation studies, with the former instrument performing slightly better than the latter. Specifically, time spent in brisk walking and vigorous-intensity PA showed stronger correlations than total PA, which was moderately correlated to HRM. Typical trends in PA research were also observed in this sample, as younger participants, males and non-minority participants had higher levels of PA. Approximately a third of this sample accumulated 150 min/week of at least moderate-intensity PA, which falls within the typical ranges reported by other countries. However, only 5% spread their PA over at least 5 days per week, therefore maximizing the health benefits associated with habitual PA. Both NZPAQs performed better than the IPAQ-long, which has been shown to consistently overestimate PA levels in other countries, and the NZ sample was no exception. Recommendations to enhance data on the NZPAQs data have been provided to their creators, including terminology, PAQ layout, and the preferred method of analysis. Physical activity surveillance is challenging, and PAQs remain the most feasible method of assessment. Until other measures become available, which are valid, affordable, and able to be administered at the population level, the NZPAQs are considered acceptable instruments for monitoring PA levels in NZ.

Measured METs from this study were compared to those listed in the US Compendium of PAs, and showed strong correlations. This study provided the opportunity to create a NZ-specific compendium of PAs, and included age-, gender-, and culturally-specific MET levels, as several traditional activities performed by the Māori population were captured during HRM. Age-specific MET levels are an important contribution to PA research, as younger individuals typically perform PAs at higher intensities, compared to older adults. In terms of public health, culturally-specific PA data highlights the contribution these PAs make towards PA and EE levels, and the baseline MET values can be utilized to increase accuracy of self-reported measures in this context. Similar data should be captured in future PA research conducted in NZ, in an effort to build on the instrument and provide more accurate EE levels by age, gender, and ethnicity.

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# APPENDICES

# APPENDIX A

## Research Forms
## Physical Activity Questionnaires

# PARTICIPANT INFORMATION SHEET

## Validation of Physical Activity Questionnaires

You are invited to take part in this survey, which is being carried out by researchers from the Auckland Medical School.

**Why are we doing this study?**
Physical activity protects against many diseases such as diabetes and heart disease. The World Health Organization and Sport & Recreation New Zealand (previously the Hillary Commission) have recently developed physical activity questionnaires that require testing to determine if they are accurate for New Zealanders.

**Who is being surveyed?**
This study will survey adults 18 years of age and older.

**Do I have to take part in this survey?**
Your participation is entirely voluntary. If you choose to take part in the study, you are free to withdraw at any time and there will be no adverse consequences. You do not have to answer all the questions and you may stop the interview at any time.

**What is involved?**
Should you wish to participate in this study, we will ask you to complete a Physical Activity Readiness Questionnaire to identify if you have any health conditions that might be aggravated by physical activity and prevent you from participating. If your health is OK for participation, we will contact you within two days to confirm your participation and schedule Visit 1.

<u>Visit 1 (about 45-60 minutes at a local community venue)</u>

- Consent Form
- Measurement of height and weight.
- We will fit you with a heart rate monitor (see diagram) and a facemask to record oxygen intake.
- Rest - you will lie face up and relax for 10-15 minutes (wearing equipment)
- Measure your resting blood pressure.
- Exercise test – cycle for 10-15 minutes (wearing equipment). The test will begin at a low intensity and advance in stages depending on your fitness level. You will be carefully observed by a health and fitness professional to minimize any risk or discomfort. You may stop at any time should you experience feelings of fatigue or any other discomfort.
- Refreshments will be provided and we will discuss the next 3 days with you.
- You will be given a heart rate monitor, receiver watch and a physical activity log to take home.
- Schedule Visit 2 and 3

<u>The Next 3 Days</u>

- A heart rate monitor will be worn around the chest, and a receiver watch around the wrist, for three days during waking hours, either at work or home, etc. - but not during sleep or showers
- Activity logs will be completed each day

<u>Visit 2 (20 to 30 minutes at home)</u>

- Completion of 2 physical activity questionnaires (global and international).
- We will collect the heart rate monitors and physical activity logs
- Download heart rate data and compare with physical activity logs

<u>Visit 3 (25 to 30 minutes at home)</u>

- Completion of 2 physical activity questionnaires (New Zealand)
- You will receive feedback on your exercise test results from Visit 1, and advice tailored to your individual exercise and fitness goals

- If you would like to receive a free screening for cholesterol and glucose levels (risk factors for heart disease and diabetes), we will provide you with a laboratory request form to take to the clinic of your choice for a free blood test.

**What about my privacy?**
The information you provide is completely confidential. No material that could personally identify you will be used in any reports from this study. The questionnaires will be locked away in a secure place. The results will be stored on computer by a code number at the University of Auckland, and will not have your name, address or any other information that could identify you.

**What are the benefits and risks of the study?**
We will provide a detailed analysis of individual energy expenditure and level of fitness; and a letter with your blood cholesterol and diabetes results, with advice to see your doctor if required.

In the unlikely even of physical injury from participating in this survey, you will be covered by the accident compensation legislation with its limitations. If you have any questions about ACC please feel free to ask the interviewer for more information before you agree to take part in this trial.

**What will happen to the survey results?**
When we have collected information on 180 participants, we will send you a summary report of your individual results and the key findings of the study. Please note that there may be a delay between your participation and the writing of such reports. You will be notified of an information night that will be held to answer any questions you may have about your summary report. Additional reports will be written and submitted to local and international organizations to be presented at conferences and published in scientific journals.

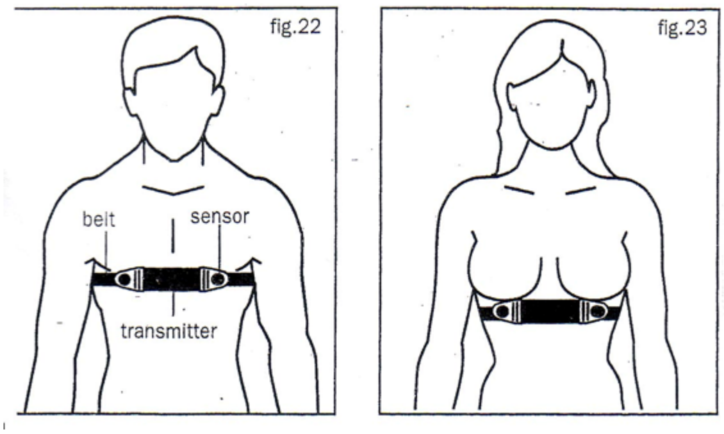
**Statement of Approval**
This study has received ethical approval from the Auckland Ethics Committee.

If you have any queries or concerns regarding your rights as a participant in this study, you may wish to contact the Health Advocates Trust, no. 0800-555-050 Northland to Franklin.

If you have any questions about the survey, please contact the following study researchers in the Department of Community Health, Auckland Medical School:

- Karen Moy (3737 599, ext 86353) or Robert Scragg (3737 599, ext.86336)

## HEART RATE MONITOR



# CONSENT FORM

## Validation of Physical Activity Questionnaires

Full Name: …………………………………………………………………………………
Surname First Middle

Address: ……………………………………………………………………………………
Street Address Suburb

Phone: ……………………………………………………………………………………...
Home Work Mobile

| | | | |
|---|---|---|---|
| ENGLISH | I wish to have an interpreter | Yes | No |
| MAORI | E hiahia ana ahau ki tangata hei korero ki ahau | Ae | Kao |
| SAMOAN | Oute mana'o e iai se fa'amatala upu | Ioe | Leai |
| TONGAN | 'Oku ke fiema'u ha fakatonulea | Io | Ikai |
| COOK ISLAND | Ka inangaro au i tetai tangata uri reo | Ae | Kare |
| NIUEAN | Fia manako au ke fakaaoga e tagata fakahokohoke | E | Nakai |

**Title of project:** Validation of Physical Activity Questionnaires

**Principal Investigators:** Dr. Robert Scragg and Karen Moy, Community Health Dept.

- I have been given, and have read a written explanation and understand what is asked of me.
- I have had an opportunity to ask questions and to have them answered.
- I understand that my participation in this study is confidential and that no material that could identify me will be used in any reports on this study.
- I have had time to consider whether to take part in this study.
- I understand that taking part in this study is voluntary and that I may withdraw from the study at any time.
- I know whom to contact if I have any questions about the study.

I consent to take part in this survey. YES NO

I consent for my blood sample to be taken. YES NO

………………………………………………………………………………………………….
Print Full Name

..……………………………………………………………………………………………
Signature of Participant Date

………………………………………………………………………………………………
Signature of Witness Date

## PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

(for people aged 15 to 69)

Please read the questions carefully and answer each one honestly: check either YES or NO.

| Yes | No | |
|---|---|---|
| ☐ | ☐ | 1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor? |
| ☐ | ☐ | 2. Do you feel pain in your chest when you do physical activity? |
| ☐ | ☐ | 3. In the past month, have you had chest pain when you were not doing physical activity? |
| ☐ | ☐ | 4. Do you lose your balance because of dizziness or do you ever lose consciousness? |
| ☐ | ☐ | 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity? |
| ☐ | ☐ | 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition? |
| ☐ | ☐ | 7. Do you know of any other reason why you should not do physical activity? |

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name: _________________________________ Date: _______________

Signature: ______________________________

## ACTIVITY SCREENING QUESTIONNAIRE

Think about the physical activities you do for *at least* 10 minutes at a time during a typical week.

How much time in total do you spend in:

- moderate activities (that cause a slight increase in breathing and heart rate); and
- vigorous activities (that make you "huff and puff")?

Office Use

Total time each week _______ minutes

How many days per week do you usually do these activities?

_______ days

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# VISIT 1 RECORDING SHEET

| Name: | Age: |
|---|---|

**Physical Measurements** **INTERVIEWER INITIALS:**

| **Height:** cm | **Weight:** kg | **BMI:** $kg/m^2$ |
|---|---|---|

**RESTING HR, BP, AND $O_2$ CONSUMPTION** Interviewer Initials:

| Minute | | HR (bpm) | | VO2 (ml/kg/min) | | Resting BP (mmHg) |
|---|---|---|---|---|---|---|
| 1 | 6 | | | | | 1st: |
| 2 | 7 | | | | | 2nd: |
| 3 | 8 | | | | | 3rd: |
| 4 | 9 | | | | | Ave. BP: / mmHg |
| 5 | 10 | | | | | Cuff Size: M L |

**TARGET HEART RATES** **FLEX HR:**

| | | |
|---|---|---|
| Age predicted HRmax: bpm | Average HRrest = bpm | Difference = |
| Target HR1: 40% HRR = (HRmax – HRrest) x 0.40 + HRrest = bpm | | |
| 50% HRR = (HRmax – HRrest) x 0.50 + HRrest = bpm | | **Target HR1:** |
| Target HR2: 60% HRR = (HRmax – HRrest) x 0.60 + HRrest = bpm | | |
| 70% HRR = (HRmax – HRrest) x 0.70 + HRrest = bpm | | **Target HR2:** |

**EXERCISE HR, BP, AND $O_2$ CONSUMPTION** **Interviewer Initials:**

| Minute | RPMs | Watts | HR | VO2 (L/min) | RPE |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

| Reason for Exercise Test Termination: |
|---|

# MONARK CYCLE ERGOMETER TEST PROTOCOLS

Warm-up stage is 5 minutes, all other stages 4 minutes
1 minute stage extensions if steady state HR not achieved in 4 minutes

**Protocol 1:** Unfit, older (>50 years) females

**Warm-up:** 30 rpms, 0.5 kg (15W) → **Stage 1:** 50 rpms, 0.5 kg (25W) → **Load Increments:** 0.1 - 0.2 kg, 5 - 10 W

**Protocol 2:** Fit young males and females

**Warm-up:** 50 rpms, 0.5 or 1.0 kg (25 or 50W) → **Load Increments:** 1.0 kg, 50 W

**Protocol 3:** Remainder, male and females

**Warm-up:** 50 rpms, 0.5 kg (25W) → **Load Increments:** 0.5 kg, 25 W

**Force and Power Conversions for Cycle Ergometer**
**Speed = 50 rpms**

| Force (kg) | Watts | Force (kg) | Watts |
|---|---|---|---|
| 0.5 | 25 | 2.5 | 125 |
| 0.6 | 30 | 3.0 | 150 |
| 0.7 | 35 | 3.5 | 175 |
| 0.8 | 40 | 4.0 | 200 |
| 0.9 | 45 | 4.5 | 225 |
| 1.0 | 50 | 5.0 | 250 |
| 1.5 | 75 | 5.5 | 275 |
| 2.0 | 100 | 6.0 | 300 |

## RATINGS OF PERCEIVED EXERTION SCALE

Instructions for RPE Scale, to be read to each participant:

"During the exercise test we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don't concern yourself with any one factor such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total, inner feeling of exertion. Try not to underestimate or overestimate your feelings of exertion; be as accurate as you can."

| Ranking | Exertion Level |
|---|---|
| 0 | Nothing at all |
| 0.3 | |
| 0.5 | Extremely Weak |
| 0.7 | |
| 1 | Very Weak |
| 1.5 | |
| 2 | Weak |
| 2.5 | |
| 3 | Moderate |
| 4 | |
| 5 | Strong |
| 6 | |
| 7 | Very Strong |
| 8 | |
| 9 | |
| 10 | Extremely Strong |

## INSTRUCTION SHEET: HEART RATE MONITORS

You have been given one heart rate monitor and wristwatch receiver, and physical activity logs for the next 3 days. The equipment should be worn from when you awake to just before bedtime (no need to wear during showers). Should you have any problems, please ring Karen or Kendra immediately at 373-7599 ext.86353.

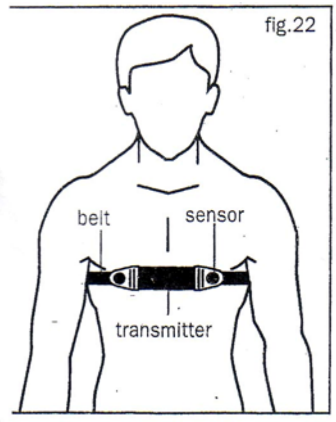
### HEART RATE MONITORS:

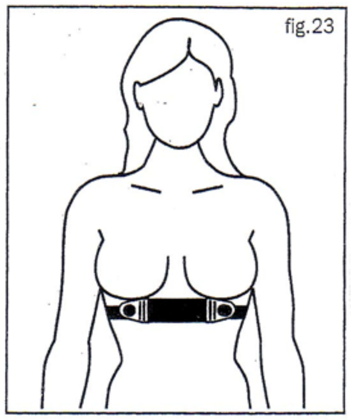
***Step 1: How to wear the monitors:***

1) Position the chest belt transmitter directly on your skin, as high under the chest/bra strap as is comfortable (see picture below). The Polar logo should be centred and right side up.
2) Wrap elastic strap around back and slide free end of the strap through the top of the belt. Twist into place to secure the belt. Adjust elastic strap so that it fits snug and comfortable.
3) The electrodes (two, oval-shaped areas located at both ends on the underside of the transmitter belt) must be wet to pick up accurate heart rate readings. Use your fingers to apply a thorough amount of water to each electrode.
4) Press the large red button on the wristwatch receiver. Your heart rate will be displayed at the bottom of the screen within 15 seconds.

<u>Troubleshooting – What if there is no heart rate reading?</u>

- Repeat the electrode wetting procedure.
- Make sure the electrodes are flat against the skin and the elastic strap is firmly tightened.



***Step 2: How to record your heart rate (see picture below):***

5) Press the down arrow (lower button on right side of watch) until you see the word “**Time"** displayed.
6) To begin recording your heart rate, press the large red button again and check that the stopwatch time has started.
7) If your heart rate is being recorded successfully, you will see a flashing vertical line along the right side of the display and the stopwatch will continue to run throughout the day.
8) Wear the wristwatch receiver on either wrist and keep within 1m of the belt.


**PROBLEMS THAT CAN OCCUR**

- A ‘**00**’ heart rate indicates there is a problem with the signal due to one of the following reasons:
  - interference: electronic objects such as copy machines, computers, vacuums, etc. Recording should resume as you step away from the object.
  - movement of the transmitter belt: make sure the elastic strap is snug
  - dry electrodes: rewet electrodes

- If recording does not automatically resume after making the following adjustments, reset the watch by pressing the stop button (lower left side of watch) and repeat process from step 5.

At the end of the day

- Take the watch and transmitter off before you go to bed. There is no need to press any buttons.
- To restart the recording on the next morning, put the transmitter belt on and hold the watch against the monitor for 5 seconds. Your heart rate and the vertical line along the right side of the display will appear.

Your Visit 2 has been scheduled for _________________ at _______am/pm

Your Visit 3 has been scheduled for _________________ at _______am/pm

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# PHYSICAL ACTIVITY LOG

**Instructions:** List all activities you performed today that caused you to breath heavier than normal. For each activity you did today, record the approximate time you began the activity. If you did any activities that are not on the list below, or performed an activity more than once, please include them under 'Other/Repeat Activities' and record the start time.

---

These are my activities for ………………………….., ……./……./…….
Day Month Year

I put the monitor on today at ……. am/pm and took it off at ……. am/pm.

| Activity | Time Activity Started | Activity | Time Activity Started |
|---|---|---|---|
| **Ballgames:** | | **Exercise Activities:** | |
| Basketball/Netball | _____ am/pm | Aerobics exercise | _____ am/pm |
| Bowling (Ten Pin, Lawn) | _____ am/pm | Cycling | _____ am/pm |
| Cricket (English) | _____ am/pm | Dancing | _____ am/pm |
| Golf | _____ am/pm | Exercise (gym or home) | _____ am/pm |
| Rugby | _____ am/pm | Gardening/Yard Work | _____ am/pm |
| Soccer | _____ am/pm | Martial Arts | _____ am/pm |
| Softball | _____ am/pm | Running/Jogging | _____ am/pm |
| Squash | _____ am/pm | Tramping | _____ am/pm |
| Tennis | _____ am/pm | Walking | _____ am/pm |
| **Maori Activities:** | | **Water Sports:** | |
| Kapa haka | _____ am/pm | Fishing (Rock, River) | _____ am/pm |
| Taiaha/Mau rakau | _____ am/pm | Rowing (Kayak, Canoe) | _____ am/pm |
| Waka | _____ am/pm | Swimming | _____ am/pm |
| Kai moana | _____ am/pm | | |
| | | **Other/Repeat Activities:** | |
| **Pacific Activities:** | | ____________________ | _____ am/pm |
| Pacific Dance | _____ am/pm | ____________________ | _____ am/pm |
| Pacific Cricket | _____ am/pm | ____________________ | _____ am/pm |
| Outrigger Canoeing | _____ am/pm | ____________________ | _____ am/pm |
| | | ____________________ | _____ am/pm |

**Office Use**

| Activity Code | SPARC Code | V/M/L | Duration | METs | Ave HR |
|---|---|---|---|---|---|
| | | | | . | |
| | | | | . | |
| | | | | . | |
| | | | | . | |
| | | | | . | |

## 3. Tobacco use

| | | |
|---|---|---|
| (a) Do you **currently smoke** any tobacco products, such as cigarettes, cigars, or pipes? | Yes ☐ No ☐ *[If "no", skip to Section 6:Physical Activity]* | ☐ |
| (b) If "yes", do you currently smoke tobacco products **daily**? | Yes ☐ No ☐ | ☐ |

## 6. Physical activity

### Occupation-related physical activity (paid or unpaid)[2]

*Reply to the following questions thinking about a typical week during the past 12 months.*

| | | |
|---|---|---|
| O1. Does your work involve mostly sitting or standing with walking for less than 10 minutes at a time? | Yes ☐ No ☐ *[If "yes", skip to T.1.]* | ☐ |
| O2. Does your work involve **vigorous activity**, like heavy lifting, digging, or construction work for at least 10 minutes at a time? | Yes ☐ No ☐ *[If "no", skip to O.3.]* | ☐ |
| (a) If "yes", on how many days in a typical week? | Days/week:_____ | ☐ |
| (b) How much time do you spend doing this on a typical day? | _____Hrs or _____min | ☐☐☐ |
| O3. Does your work involve **moderate-intensity activities**, like brisk walking or carrying light loads for at least 10 minutes at a time? | Yes ☐ No ☐ *[If "no", skip to question T.1.]* | ☐ |
| (a) If "yes", on how many days in a typical week? | Days/week: _____ | ☐ |
| (b) How much time do you spend doing this on a typical day? | _____Hrs or _____min | ☐☐☐ |
| O4. How long is your typical workday? | ____Hrs | ☐☐ |

### Travel-related physical activity

| | | |
|---|---|---|
| T1. Do you walk or cycle (pedal bicycle) to and from places (to work, to the market, to church, etc.) for at least 10 minutes at a time? | Yes ☐ No ☐ *[If "no", skip to L.1.]* | ☐ |
| (a) If "yes", on how many days in a typical week? | Days/week: _____ | ☐ |
| (b) How much time do you spend travelling this way on a typical day? | ____Hrs or ____min | ☐☐☐ |

## Physical activity for recreation, sport or leisure

*This set of questions is about activities you do in your leisure-time for recreation, such as sport (that is, activities aside from your work or travel, and not the activities already mentioned).*

L1. Does your recreation, sport and leisure time involve mostly sitting, reclining, or standing, with walking for less than 10 minutes at a time? Yes ☐ No ☐

L2. Do you do **vigorous activities** like weight lifting, running, or strenuous sports in your RSL-time for at least 10 minutes at a time? Yes ☐ No ☐ *[If "no", skip to L.3.]*

(a) If "yes", on how many days in a typical week? Days/week: ____

(b) How much time do you spend doing this on a typical day? ____Hrs or ____min

L3. Do you do moderate-intensity activities, like brisk walking, cycling or swimming, in your RSL-time for at least 10 minutes at a time? Yes ☐ No ☐ *[If "no", skip to R.1.]*

(a) If "yes", on how many days in a typical week? Days/week: ____

(b) How much time do you spend doing this on a typical day? ____Hrs or ____min

## Sitting / reclining

*This question is about sitting or reclining. Think back over the **past 7 days** to time spent at work, at home, or during recreation time, including time spent sitting at a desk, visiting friends, reading, or watching television – but not counting time spent sleeping.*

R1. How much time do you spend sitting or reclining on a typical day? ____Hrs or ____min

"Smoking daily" means to have a smoke at least once a day. Note that people, who smoke every day, except on days of religious fasting, are still considered daily smokers.

"Work" refers to the total of all activities related to things that the respondent *has* to do, be it paid or unpaid, such as paid employment, housework, household chores, harvesting food, fishing or hunting for food, seeking employment, etc.

# INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. This is part of a large study being conducted in many countries around the world. Your answers will help us to understand how active we are compared with people in other countries. The questions are about the time you spent being physically active in the **last 7 days**. They include questions about activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Your answers are important.

**Please answer each question even if you do not consider yourself to be an active person.**

**THANK YOU FOR PARTICIPATING.**

In answering the following questions,

- **vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder that normal.
- **moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder that normal.

***PART 1: JOB-RELATED PHYSICAL ACTIVITY***

The first section is about your work. This includes paid jobs, farming, volunteer work, course work and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

**1a.** Do you currently have a job or do any unpaid work outside your home?

☐ Yes

☐ No *[If No, go to PART 2: TRANSPORTATION]*

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This *does not* include traveling to and from work.

**1b.** During the last 7 days, on how many days did you do *vigorous* physical activities like heavy lifting, digging, heavy construction, or climbing up stairs *as part of your work*? Think about *only* those physical activities that you did for at least 10 minutes at a time.

**________ days per week**

**or**

**none**

*[If none, go to question 1d]*

**1c.** How much time in total did you usually spend on one of those days doing vigorous physical activities as part of your work

**_____ hours ______ minutes**

**1d.** Again, think about *only* those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do *moderate* physical activities like carrying light loads *as part of your work?* Please *do not* include walking.

**________ days per week**

**or**

**none**

*[If none, go to question 1f]*

**1e.** How much time in total did you usually spend on one of those days doing moderate physical activities *as part of your work?*

**_____ hours ______ minutes**

**1f** During the last 7 days, on how many days did you *walk* for at least 10 minutes at a time *as part of your work*? Please *do not* count any walking you did to travel to or from work.

**________ days per week**

**or**

**none**

*[If none, go to PART 2: TRANSPORTATION*

**1g.** How much time in total did you usually spend walking on one of those days walking *as part of your work?*

**_____ hours ______ minutes**

***PART 2: TRANSPORTATION PHYSICAL ACTIVITY***

These questions are about how you traveled from place to place, including to places like work, stores, movies and so on.

**2a.** During the last 7 days, on how many days did you *travel* in a motor vehicle like a train, bus, car or tram?

**________ days per week**

**or**

**none**

*[If none, go to question 2c]*

**2b.** How much time in total did you usually spend on one of those days *traveling in a car, bus, train or other kind of motor vehicle?*

**_____ hours ______ minutes**

Now think *only* about the *bicycling* and *walking* you might have done to travel to and from work, to do errands, or to go from place to place.

**2c.** During the last 7 days, on how many days did you *bicycle* for at least 10 minutes at a time *to go from place to place*?

**________ days per week**

**or**

**none**

*[If none, go to question 2e]*

**2d.** How much time in total did you usually spend on one of those days to bicycle *from place to place*?

**_____ hours ______ minutes**

**2e.** During the last 7 days, on how many days did you *walk* for at least 10 minutes at a time *to go from place to place?*

**________ days per week**

**or**

**none**

*[If none, go to PART 3: HOUSEWORK, HOUSE MAINTENANCE AND CARING FOR FAMILY]*

**2f.** How much time in total did you usually spend on one of those days walking *from place to place*?

**_____ hours ______ minutes**

***PART 3. HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

This section is about some of the physical activities you might have done in the last 7 days *in and around your home*, like housework, gardening, yard work, general maintenance work, and caring for your family.

**3a.** Think about *only* those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do *vigorous* physical activities like heavy lifting, chopping wood, shoveling snow, or digging *in the garden or yard?*

**________ days per week**

**or**

**none**

*[If none, go to question 3c]*

**3b.** How much time in total did you usually spend on one of those days doing vigorous physical activities *in the garden or yard*?

**_____ hours ______ minutes**

**3c.** Again, think about *only* those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do *moderate* activities like carrying light loads, sweeping, washing windows, and raking *in the garden or yard?*

**________ days per week**

**or**

**none**

*[If none, go to question 3e]*

**3d.** How much time in total did you usually spend on one of those days doing moderate physical activities *in the garden or yard?*

**_____ hours ______ minutes**

**3e.** Once again, think about *only* those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do *moderate* activities like carrying light loads, washing windows, scrubbing floors and sweeping *inside your home?*

**________ days per week**

**or**

**none**

*[If none, go to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY]*

**3f.** How much time in total did you usually spend on one of those days doing moderate physical activities *inside your home*?

**_____ hours ______ minutes**

***PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY***
This section is about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do NOT include any activities you have already mentioned.

**4a.** *Not counting any walking you have already mentioned*, during the last 7 days, on how many days did you walk for at least 10 minutes at a time *in your leisure time*?

**________ days per week**

**or**

**none**
*[If none, go to question 4c]*

**4b.** How much time in total did you usually spend on one of those days walking *in your leisure time?*

**_____ hours ______ minutes**

**4c.** Think about *only* those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do *vigorous* physical activities like aerobics, running, fast bicycling, or fast swimming *in your leisure time*?

**________ days per week**

**or**

**none**
*[If none, go to question 4e]*

**4d.** How much time in total did you usually spend on one of those days doing vigorous physical activities *in your leisure time*?

**_____ hours ______ minutes**

**4e.** Again, think about *only* those physical activities that you did for a t least 10 minutes at a time. During the last 7 days, on how many days did you do *moderate* physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis *in your leisure time?*

**________ days per week**

**or**

**none**
*[If none, go to PART 5: TIME SPENT SITTING]*

**4f.** How much time in total did you usually spend on one of those days doing moderate physical activities *in your leisure time*?

**_____ hours ______ minutes**

***PART 5: TIME SPENT SITTING***
The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

**5a.** During the last 7 days, how much time in total did you usually spend *sitting* on a *week day*?
**_____ hours ______ minutes**

**5b.** During the last 7 days, how much time in total did you usually spend *sitting* on a *weekend day*?

**_____ hours ______ minutes**

## NZPAQ-SF

Start Time:

**PHYSICAL ACTIVITY**
The following questions ask about physical activity that you may have done in the past 7 days. I will ask you separately about brisk walking, moderate activity, and vigorous activity.

**Walking**

1. During the last 7 days, on how many days did you **walk at a brisk pace –** a brisk pace is a pace at which you are breathing harder than normal? This includes walking at work or school, while traveling from place to place, at home, and at any activities that you did solely for recreation, sport, exercise or leisure.

   Think *only* about brisk walking done at least for 10 minutes at a time.

   - O _______days per week (GO TO 2)
   - O None (GO TO 3)

2. How much time did you typically spend walking at a brisk pace on **each** of those days?

   - O _____ hours _______minutes

**Moderate physical activity**

3. During the last 7 days, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, doubles tennis, or other activities like those on this show card? (moderate activities *showcard*). Do not include walking of any kind.

   Think about *only* those physical activities done at least for 10 minutes at a time.

   - O _______days per week (GO TO 4)
   - O None (GO TO 5)

4. How much time did you typically spend on **each** of those days doing moderate physical activities?

   - O _____ hours _______minutes

**Vigorous physical activity**

5. During the last 7 days, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, fast bicycling, or other activities like those on this showcard? (vigorous activities *showcard*)

Think about *only* those physical activities done at least for 10 minutes at a time)

- O _______days per week (GO TO 6)
- O None (GO TO 7)

6. How much time did you typically spend on **each** of those days doing vigorous physical activities?

- O _____ hours _______minutes

7. Thinking about all your activities (vigorous or moderate including brisk walking), on how many of the last 7 days were you active for? ("Active" means doing 15 minutes or more of vigorous activity or 30 minutes or more of moderate activity, or brisk walking).

- O _______days per week
- O None

8. Describe your physical activity over the last six months. Regular physical activity means at least 15 minutes of vigorous activity (makes you 'huff and puff') or 30 minutes of moderate activity (caused a slight but noticeable increase in breathing and heart rate) each day for 5 or more days each week. Include brisk walking.

- O I am not regularly physically active and do not intend to be so in the next 6 months
- O I am not regularly physically active but am thinking about starting to do so in the next 6 months
- O I do some physical activity but not enough to meet the description of regular physical activity
- O I am regularly physically active but only began in the last 6 months
- O I am regularly physically active and have been so for longer than 6 months

Stop Time:

Total Time

## SHOWCARD FOR NZPAQ-SF

### Moderate Physical Activity

| |
|---|
| Badminton (Social) |
| Ballroom dancing |
| Bowls - Indoor |
| Bowls - Outdoor/Lawn |
| Carrying light loads |
| Cricket - outdoors (batting and bowling) |
| Cycling - recreational (not mountain biking) - less than 15 km/hr |
| Deer hunting |
| Doubles tennis |
| Electrical work |
| Exercising at home |
| Farming |
| Golf |
| Gardening |
| Heavy gardening |
| Heavy cleaning |
| Horse riding/Equestrian |
| House renovations |
| Kayaking - slow |
| Machine tooling - operating lathe, punch press, drilling, welding |
| Manual lawnmower |
| Massage |
| Motor sports (motorcycling/trail biking, motor racing) |
| Plastering |
| Plumbing |
| Raking/planting |
| Skate boarding |
| Surfing/body boarding |
| Vacuuming |
| Yachting/sailing/dingy sailing |

## SHOWCARD FOR NZPAQ-SF

### Vigorous Physical Activity

| | |
|---|---|
| Boxing | Race walking |
| Aerobics | Running/jogging/cross-country |
| Kayaking – fast | Judo, karate etc. |
| Athletics (track and field) | Softball (running/pitching only) |
| Aquarobics | Squash |
| Skiing | Surf life saving |
| Badminton (Competitive) | Swimming |
| Basketball | Table tennis |
| Mountain biking | Tennis |
| Cricket - indoors (batting and bowling) | Touch football |
| Cycling - competitive | Tramping |
| Cycling - recreational (not mountain biking) - more than 15 km/hr | Triathlon |
| Rock climbing | Volleyball |
| Exercise classes/going to the gym (other than aerobics work)/weight training | Water polo |
| Netball | Carrying heavy loads |
| Soccer | Forestry |
| Rowing | Horse racing |
| Rugby League | Heavy construction |
| Rugby Union | Digging ditches |
| Hockey | Chopping or sawing wood |

# NZSPAS WITH NZPAQ–LF

Start Time: ……………

**Background questions**

**General Data**
Date survey completed: --/--/---- (dd/mm/yyyy)

Date of Birth: --/--/---- (dd/mm/yyyy)

Gender: Male/Female

Height: ____ (cm)

Weight: ____ (kg)

**Ethnicity Question**
Which ethnic group(s) do you belong to?

| | |
|---|---|
| | New Zealand European --- 01 |
| | Maori --- 02 |
| | Samoan --- 03 |
| | Cook Island Maori --- 04 |
| | Tongan --- 05 |
| | Niuean --- 06 |
| | Chinese --- 07 |
| | Indian --- 08 |
| | Other (such as Dutch, Japanese, Tokelauan) --- 09<br>Please state: ______________________ |

**Stage of Behaviour Change**
Describe your physical activity over the last six months. Regular physical activity means at least 15 minutes of vigorous activity or 30 minutes of moderate activity each day for 5 or more days each week.

| | |
|---|---|
| **1** | I am not regularly physically active and do not intend to be so in the next 6 months. |
| **2** | I am not regularly physically active but am thinking about starting to do so in the next 6 months. |
| **3** | I do some physical activity but not enough to meet the description of regular physical activity (at least 30 minutes of moderate |
| **4** | I am regularly physically active but only began in the last 6 months. |
| **5** | I am regularly physically active and have been so for longer than 6 months. |

| ACTIVITIES | 12 month | 4 weeks | No. days | 2 weeks | 7 days |
|---|---|---|---|---|---|
| Aerobics | 01 | 01 | | 01 | 01 |
| Aquarobics (aqua/water jogging) | 02 | 02 | | 02 | 02 |
| Athletics (track and field) | 03 | 03 | | 03 | 03 |
| Badminton | 04 | 04 | | 04 | 04 |
| Basketball | 05 | 05 | | 05 | 05 |
| Bowls - outdoor/lawn | 06 | 06 | | 06 | 06 |
| Bowls - indoor | 07 | 07 | | 07 | 07 |
| Cricket - outdoors | 08 | 08 | | 08 | 08 |
| Cricket - indoors | 09 | 09 | | 09 | 09 |
| Cycling - competitive | 10 | 10 | | 10 | 10 |
| Cycling - recreational | 11 | 11 | | 11 | 11 |
| Exercise classes/gym/weights | 12 | 12 | | 12 | 12 |
| Exercising at home | 13 | 13 | | 13 | 13 |
| Fishing | 14 | 14 | | 14 | 14 |
| Gardening | 15 | 15 | | 15 | 15 |
| Golf | 16 | 16 | | 16 | 16 |
| Hockey | 17 | 17 | | 17 | 17 |
| Horse riding/Equestrian | 18 | 18 | | 18 | 18 |
| Motor sports | 19 | 19 | | 19 | 19 |
| Mountain biking | 20 | 20 | | 20 | 20 |
| Netball | 21 | 21 | | 21 | 21 |
| Rowing | 22 | 22 | | 22 | 22 |
| Rugby Union | 23 | 23 | | 23 | 23 |
| Rugby League | 24 | 24 | | 24 | 24 |
| Rugby - Touch | 25 | 25 | | 25 | 25 |
| Running/jogging | 26 | 26 | | 26 | 26 |
| Shooting (rifle & pistol) | 27 | 27 | | 27 | 27 |
| Skiing - snow, grass | 28 | 28 | | 28 | 28 |
| Soccer | 29 | 29 | | 29 | 29 |
| Softball | 30 | 30 | | 30 | 30 |
| Squash | 31 | 31 | | 31 | 31 |
| Surfing/body boarding | 32 | 32 | | 32 | 32 |
| Surf life saving | 33 | 33 | | 33 | 33 |
| Swimming | 34 | 34 | | 34 | 34 |
| Tennis | 35 | 35 | | 35 | 35 |
| Tramping | 36 | 36 | | 36 | 36 |
| Triathlon | 37 | 37 | | 37 | 37 |
| Volleyball | 38 | 38 | | 38 | 38 |
| Yachting/sailing | 39 | 39 | | 39 | 39 |
| Walking for 10-30 minutes | 40 | 40 | | 40 | 40 |
| Walking for over 30 minutes | 41 | 41 | | 41 | 41 |
| | | | | | |
| **Hakinakina Maori** | | | | | |
| Kapa haka | 42 | 42 | | 42 | 42 |
| Taiaha | 43 | 43 | | 43 | 43 |
| Mau rakau | 44 | 44 | | 44 | 44 |
| Waka | 45 | 45 | | 45 | 45 |
| | | | | | |
| **OTHER ACTIVITIES** | 46 | 46 | No. Days | 46 | 46 |
| 1. | Y/N | Y/N | | Y/N | Y/N |
| 2. | Y/N | Y/N | | Y/N | Y/N |
| 3. | Y/N | Y/N | | Y/N | Y/N |

**Main Physical Activity Table (NZPAQ-LF)** - Activities performed in the last 7 days (Record time spent on each activity each day)

Date of Day 1: [ | ] Day [ | ] Month [ | ] Year

Day of Week:

| Context | Activity Code | TOTAL TIME (min) (L, M, V) | Day 1 | | Day 2 | | Day 3 | | Day 4 | | Day 5 | | Day 6 | | Day 7 | | TOTAL TIME *(hrs/mins)* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mod | Vig | Mod | Vig | Mod | Vig | Mod | Vig | Mod | Vig | Mod | Vig | Mod | Vig | Mod | Vig |
| Physical Recreation & Sport | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Transport | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Occupation | | | | | | | | | | | | | | | | | | |
| Job Title | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | TOTAL | | | | | | | | | | | | | | | | | |

| | Inactivity | Day 1 (hrs/mins) | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | TOTAL TIME *(hrs/mins)* |
|---|---|---|---|---|---|---|---|---|---|
| | Sitting or standing still or lying down | | | | | | | | |
| | Sleeping | | | | | | | | |
| | **Total Inactivity** | | | | | | | | |
| | **Resistance Training** | | | | | | | | |

**Stair-climbing question**:

Q.42b "Over the last 7 days, that is from....day until yesterday, on how many days did you go up or down one or more flights of stairs - a flight being one story?"

Q.42c "How many flights of stairs did you typically go up or down per day, on that/those day/s? Please count up and down separately."

**Socio-economic status questions**

Q.51 **SHOW CARD 6**

"Which of these best describes the **total gross** income before tax of all the people at your address? That includes benefit and retirement income, as well as paid income from all sources."

(IF NOT KNOWN, ASK FOR RESPONDENT'S INDIVIDUAL INCOME)

| | | | |
|---|---|---|---|
| No income | ----------- 01 | $30,001 - $40,000 | --- 08 |
| $1,000 - $5,000 | ----- 02 | $40,001 - $50,000 | --- 09 |
| $5,001 - $10,000 | --- 03 | $50,001 - $70,000 | --- 10 |
| $10,001 - $15,000 | --- 04 | $70,001 - $100,000 | --- 11 |
| $15,001 - $20,000 | --- 05 | $100,000 or more | --- 12 |
| $20,001 - $25,000 | --- 06 | Not stated/Refused | --- 13 |
| $25,001 - $30,000 | --- 07 | | |

HOUSEHOLD OR INDIVIDUAL INCOME:
Respondent only - 1
Total Household Income - 2

Stop Time:

**TOTAL TIME TO COMPLETE**:

## NZPAQ-LF SHOWCARDS

### Showcard 1 - Sport and Physical Recreation Activities

| | | | |
|---|---|---|---|
| 1. | Aerobics | 30. | Softball |
| 2. | Aquarobics | 31. | Squash |
| 3. | Athletics (track and field) | 32. | Surfing/body boarding |
| 4. | Badminton | 33. | Surf life saving |
| 5. | Basketball | 34. | Swimming |
| 6. | Bowls-outdoor/lawn | 35. | Tennis |
| 7. | Bowls-indoor | 36. | Tramping |
| 8. | Cricket - outdoors | 37. | Triathlon |
| 9. | Cricket - indoors | 38. | Volleyball |
| 10. | Cycling - competitive | 39. | Yachting/sailing/dinghy sailing |
| 11. | Cycling – recreational (not mountain biking) | 40. | Walking for enjoyment or exercise (10 - 30mins) |
| 12. | Exercise classes/going to the gym (other than aerobics work)/weight training | 41. | Walking for enjoyment or exercise (>30mins) |
| 13. | Exercising at home | | |
| 14. | Fishing | | |
| 15. | Gardening | | **Maori Activities** |
| 16. | Golf | 42. | Kapa haka |
| 17. | Hockey | 43. | Taiaha |
| 18. | Horse riding/Equestrian | 44. | Mau rakau |
| 19. | Motor sports (motorcycling, trail biking, motor racing) | 45. | Waka |
| 20. | Mountain biking | | |
| 21. | Netball | 46. | Other (specify) |
| 22. | Rowing | | |
| 23. | Rugby Union | | |
| 24. | Rugby League | | |
| 25. | Rugby – Touch | | |
| 26. | Running/jogging/cross-country | | |
| 27. | Shooting (rifle & pistol) | | |
| 28. | Skiing | | |
| 29. | Soccer | | |

**Light Activity**: Light activity is activity that does **not** cause you to breathe harder than normal.
**Moderate Activity**: Will cause a slight, but noticeable, increase in breathing and heart-rate.
**Vigorous Activity**: Vigorous activity is activity that makes you "huff and puff", and where talking in full sentences between a breath is difficult.

## Showcard 2 - Transport

| | |
|---|---|
| 1. | Walking |
| 2. | Cycling[a] |
| 3. | Running |
| 4. | Other[b] |

a) Cycling includes riding a tandem, recumbent or mountain bike to work.
b) Other may include roller-blading, non-motorised scooter, skateboarding, rowing/kayaking, skiing or horse riding.

## Show card 3 - occupation

| Light Intensity | Moderate Intensity | Vigorous Intensity |
|---|---|---|
| Tailor | Heavy cleaning | Carrying heavy loads |
| Office work | Farming | Forestry |
| Standing - bartending, store clerk, filing, photocopying | Machine tooling - operating lathe, punch press, drilling, welding | Horse racing |
| Light cleaning | Massage | Heavy construction |
| Driving | Carrying light loads | Digging ditches |
| Sitting at computer | Gardening | Chopping or sawing wood |
| | Plumbing | |
| | Plastering | |
| | Electrical work | |
| | Welding | |

## Show card 4 - Cultural/Other/Incidental Activity

| Cultural Activities | Home Activities | Voluntary Work |
|---|---|---|
| Cultural Dance | Sweeping | Playing with children |
| Traditional games | Heavy cleaning | Walking at a moderate speed |
| | Mopping | Cleaning church/other |
| | Vacuuming | |
| | Carrying boxes/moving | |
| | Carpentry | |
| | Painting, papering | |
| | All home repairs | |
| | All gardening | |
| | Lawn mowing | |

## Show card 5 - Inactivity

| Examples of Inactivity |
|---|
| Watching TV or movie |
| Doing nothing |
| Lying in bed awake |
| Listening to music |
| Reading |
| Talking on phone |
| Meditating |
| Kneeling e.g. praying |
| Writing |
| Standing in a line or queue |
| Vehicle passenger |

## Show card 6 - Socio-economic Status

| | | | |
|---|---|---|---|
| 01 | No income | 08 | $30,001 - $40,000 |
| 02 | $1,000 - $5,000 | 09 | $40,001 - $50,000 |
| 03 | $5,001 - $10,000 | 10 | $50,001 - $70,000 |
| 04 | $10,001 - $15,000 | 11 | $70,001 - $100,000 |
| 05 | $15,001 - $20,000 | 12 | $100,000 or more |
| 06 | $20,001 - $25,000 | 13 | Not stated/Refused |
| 07 | $25,001 - $30,000 | | |

## QUESTIONS FOR ADMINISTERING NZSPAS AND NZPAQ-LF

Q.1 **SHOW CARD 1**

"On this card is a list of sports and physical activities. Would you please tell me whether you have taken part in any of them during the last 12 months? Please don't count any activities linked to your job, teaching, coaching, refereeing, or sports administration."

***(Circle all activities in '12 Month' Column)***

Q.2 "Are there any **other** sports or physical activities that are not shown on this card, that you've taken part in during the last 12 months?" Please don't count activities such as lawn mowing, housework, house maintenance, or any physical activity linked to your job."

***(Circle code 46 under '12 Month' Column AND write in "OTHER ACTIVITIES" in spaces provided. IF NO activities mentioned for last 12 months, GO TO Transport section of Main Physical Activity Table***

Q.3 FOR **ALL** ACTIVITIES circled in '12 Month' column, ask "Did you take part in ... <ACTIVITY> during the last 4 weeks?"

***(Circle all activities in '4 weeks' column. If taken part in one or more "OTHER ACTIVITIES" in last 4 weeks, circle 46 in '4 weeks' column and Y or N for each activity).*** IF NO activities mentioned for last 4 weeks, GO TO Transport section of Main Physical Activity Table.

Ask Q.4 & Q.5 for all activities taken part in during the last 4 weeks, including "OTHER ACTIVITIES".

Q.4 "On how many days in the last 4 weeks have you taken part in ...<ACTIVITY>? Please include days when you were training or practising, as well as playing or taking part."

***(Write in total number of days for each activity. (MAXIMUM = 28). For "OTHER ACTIVITIES" record the total number of days spent taking part in each OTHER activity).***

Q.5a "Did you take part in <ACTIVITY> in the last 2 weeks?"

***IF NO activities mentioned in the last 2 weeks, GO TO Transport section of Main PhysicalActivity Table.***

Ask Q.5b for all activities taken part in during the last 2 weeks, including "OTHER ACTIVITIES".

Q.5b " FOR **ALL** ACTIVITIES circled in '2 weeks' column, ask "Did you take part in ... <ACTIVITY> during the last 7 days?"

***Circle all activities in '7 days' column. For each activity circled, ask*** "Now, thinking back over the last 7 days, how much time did you spend altogether in...<ACTIVITY>?"

***For each activity, enter Activity code on Main Physical Activity Table AND record total time (L, M, V) in minutes. If coded '46', record total time spent on all "OTHER ACTIVITIES".***

# MAIN PHYSICAL ACTIVITY TABLE (NZPAQ-LF)

**TRANSPORT - SHOWCARD 2**

"Think about all the non-motorised transport that you have used in the last 7 days. Transport includes from home to work return, transport to the shops and for chores and for getting from place to place. Count only those performed for a minimum of 10 minutes that have not already been reported on this chart."

**OCCUPATION - SHOWCARD 3**

Ask for participant's job title and record in table.

"This show card provides some examples of activities and how intense they may be. Many jobs will have some components that are of moderate or vigorous intensity and some time that is of light intensity. Try to estimate how much time is spent in moderate and vigorous intensity activity."

**CULTURAL/OTHER/INCIDENTAL ACTIVITY - SHOWCARD 4**

"This show card provides some examples of cultural/other/incidental activities. Count only those activities performed in the last 7 days for a minimum of 10 minutes that have not already been reported. Try and estimate how much activity was performed at moderate and vigorous intensities."

**INACTIVITY - SHOWCARD 5**

"This show card provides some examples of inactivity. Not counting time spent at work, try to estimate how much time was spent being inactive for each of the last 7 days."

**SOCIO-ECONOMIC STATUS - SHOWCARD 6**

"Which of these best describes the **total gross** income before tax of all the people at your address? That includes benefit and retirement income, as well as paid income from all sources."

# ADDITIONAL PHYSICAL ACTIVITY CODES

SPORT AND PHYSICAL RECREATION ACTIVITIES

| | |
|---|---|
| 46 | Martial Arts/Dancing |
| 47 | Yoga |
| 48 | Boxing |
| 49 | Kayaking |
| 50 | Other (trampoline, petanque, table tennis) |

TRANSPORT

| | |
|---|---|
| 200 | Walking |
| 201 | Cycling |
| 202 | Running |
| 203 | Other |

OCCUPATION

| | |
|---|---|
| 300 | Carrying light loads |
| 301 | Moving/lifting light loads |
| 302 | Moving/lifting/carrying heavy loads |
| 303 | Walking |
| 304 | Heavy Cleaning |
| 305 | Light/Moderate Cleaning |
| 306 | Other (lawn mowing, planting) |

OTHER/INCIDENTAL

| | |
|---|---|
| 400 | General cleaning |
| 401 | Walking - light, non-cleaning (ready to leave, shut/lock doors, close windows) |
| 402 | Painting (inside) |
| 403 | Self care |
| 404 | Moving furniture |
| 405 | Multiple household activities (moderate) |
| 406 | Lawn mowing |
| 407 | Playing with children |
| 408 | Carrying light to moderate loads |
| 409 | Carrying heavy loads |
| 410 | Home repair |
| 411 | Traditional game |
| 412 | Childcare |
| 413 | Coaching sport |
| 414 | Emotion/Stress/Sport spectator |
| 415 | Socialising/eating |
| 416 | Religious/Church activity |
| 417 | Cultural Dance |
| 418 | Kitchen Activity - cooking, washing dishes |
| 419 | Clean/vacuum/tidy car |
| 420 | Cleaning church |
| 421 | Other (un/packing, non-church singing, shopping, playing instrument, laundry, auto repair, board games, caring for animals, take out rubbish) |

| | |
|---|---|
| 500 | Unknown activity |

**Samoan Translations**

Physical Activity Readiness Quesstionnaire
Instruction Sheet: Heart Rate Monitoring
Physical Activity Log
NZPAQ-LF Showcards

## O Fesili Täpena mo Gaoioiga o le tino

(mo tagata e 15 tausaga aga'i le 69)

Faamolemole, faitau lelei ma tali mai fesili ta`itasi ma lou faamaoni: kolosi le IOE po'o le LEAI.

| Ioe | Leai | |
|---|---|---|
| ☐ | ☐ | 1. Pe sa fai atu ia te oe lau föma`i ua iai se faaletonu i lou fatu ma e tatau lava ona faia na`o gaoioiga na ia faatonuina ai oe e fai. |
| ☐ | ☐ | 2. Pe e te lagona le tïgä o lou fatafata pe`ä e faia ni gaoioiga/toleniga/ faamälositino? |
| ☐ | ☐ | 3. I le masina e tasi ua mavae, pe sa e lagona se tïgä i lou fatafata i se taimi e te lë faia ai ni gaoioiga? |
| ☐ | ☐ | 4. Pe`ä lë sagatonu lou tino pe`ä e tu i luga ona o le niniva po o le lë malamalama o lou mäfaufau? |
| ☐ | ☐ | 5. Pe ua iai se faalëtonu i ou ivi po o gaugäivi (joint) e mäfua (made worse), ona ua sui gaoioiga a lou tino? |
| ☐ | ☐ | 6. Po ua faatonu (prescribing) i lau föma`i ni vai / fuäla`au i le taimi nei ona o le toto maualuga po o le faalëtonu o lou fatu? |
| ☐ | ☐ | 7. Pe e te iloa nisi mäfua`aga ua taofia ai oe e te faia ni gaoioiga tiotio? |

Ua `ou faitauina, malamalama ma faatumu ai loa lenei pepa fesili. Ua `ou talia uma fesili ma le faamalieina äto`atoa o lo`u loto.

***Igoa:*** ________________________________ ***Aso ua fai ai:*** _______________

***Saini:*** _____________________________

## ITULAU FA’ATONUGA: MASINI FUA FATU MA LE PU’EGA O GAOIOIGA TAU I LE TINO.

Ua tauaaoina atu iate oe se masini fua fatu faatasi ai ma se uati ma ni pepa e pu`e/tusi ai au toleniga mo aso e 3 o lumanai ai nei. E tatau ona fusi ane i lou tino le masini i le taimi e te ala ai (pe`ä uma ona tä`ele) se`ia o`o i le taimi e te sauni ai e moe. Afai e iai ni au fesili faafeso`ota`i  le numera 373-7599 ext. 86353

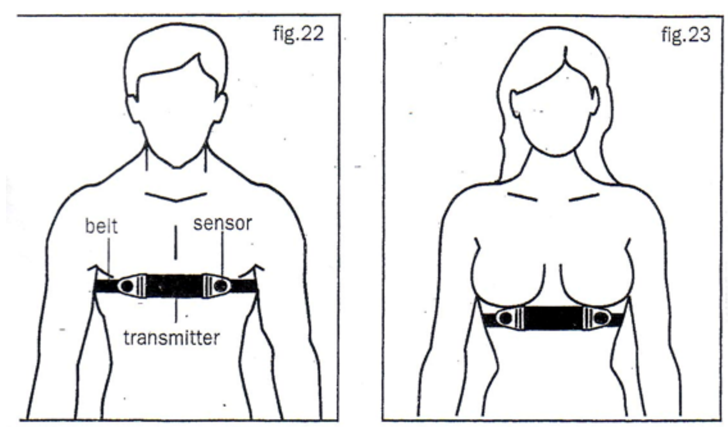
**MASINI FUA FATU:**

***Laasaga 1: E fusi fa’apea le masini:***

1) Faatulaga lelei le fusipa`u, ia taoto tonu i luga i le pa`u o lou fatafata, ia gata mai le maualuga i lalo ifo tonu o lou fatafata po o le papa o le tama`ita`i ma ia `aua ne`i fufusi tele (va`ai i le ata i lalo). E tatau ona faafeagai tonu upu nei ‘The Polar’ i le ogätotonu ma ia faasaga sa`o i luga.
2) Fusi le pa`u meme`i i lou tua ma tui le amataga o le fusi i totonu o le fusipa`u. Mimilo se`ia mau lelei le fusipa`u. Faasa’au le pa`u meme`i ina ia fusi ma  ia mau lelei i lau faalogo ae `aua ne`i fufusi tele.
3) E tatau ona susü li`o uila (electrodes – o li`o e lua i itü e lua i lalo ifo o le … Fusipa`u) ina ia maua lelei le tätäaga o lou fatu. Faaaogä ou tama`ilima e faasusü lelei ai li`o uila taitasi.
4) O`omi le kï läpo`a lanumümü i le uati. O le a faaali mai le tätä o lou fatu i lalo o le tioata manino o le uati i le isi 15 sekone o lumana`i ai.

<u>Faasa`oga o faalavelave – Pe afai ua leai se faaaliga mai o le tätä o lou fatu?</u>

- Toe faasusü lelei li`o uila.
- Ia mautinoa lelei o loo ta`ota lelei li`o uila i lou pa`u ma ia mau lelei le fusiga o le pa`u meme`i.



***La`asaga 2: E faapenei ona  pu`e le tätä o lou fatu (va`ai i le ata i le itülau o soso`o ai)***

*5)* O`omi le faa`äü o loo faasaga i lalo ( le kï pito i lalo i le itü taumatau o le uati) se`ia e va`aia le upu "Time" ua faaali mai.

*6)* A amata le pu`ega o le tätä o lou fatu, ia toe o`omi le kï mümü läpo`a ma ia siaki le uati ina ua amata ona pu`e po`o tau le taimi.

7) Afai ua pu`e lelei le tätä o lou fatu, o lona uiga e te va`ai foi i se laina tüsa`o ua `emo`emo i le itü taumatau o le faatioata ma e faaauau pea le galuega a le uati pu`etaimi i le aso atoa.

8) Fusi le uati i so`o se tapulima ma ia `aua ne`i silia i le mita e tasi le va po o le mamao ese atu ma le fusipa`u.

**<u>FAASA`OGA O FAALAVELAVE E MAFAI ONA MAUA</u>**

- Afai ua faaali mai e le masini fua fatu, le '**00**'  o  lona uiga o loo iai se faafïtäuli ona o se tasi o mäfua`aga nei:
  - ua äiäina e: ni isi masini faa`eletise e pei o masini e kopi ai pepa, komipiuta, masini e mimitiina le pefu, mmf. E tatau ona toe amataina le pe`uga pe a e alu ese ma sea masini.
  - Ua gaioi po ua lë mau lelei le fusipa`u: Ia mautinoa ua lelei le fusipa`u i lou fatafata
  - Ua mago li`o uila: toe faasusü lelei li`o uila.

- Afai e toe amata le pu`ega pe a uma ona toe fai ni faasa`oga o loo tä`ua i lalo, toe seti le uati i le o`omiina lea o le kï täofi (le kï pito i lalo i le itu tauagavale o le uati) ona toe amata mai lea i le faatonuga lona lima.
- Ave ese le uati ma le fusipa`u i le taimi ole`ä e sauni ai e te moe. Ina ia toe amataina  le pu`ega, toe fusi le fusipa`u ma u`u le uati faapipi`i i le masini mo se 5 sekone

Lau asiasiga lona 2 ua fuafuaina mo le _________ pe`ä ta le ____ i le taeao/afiafi

Lau asiasiga lona 3 ua fuafuaina mo le _________ pe`ä ta le ____ i le aeao/afiafi.

THE UNIVERSITY OF AUCKLAND
FACULTY OF MEDICAL AND HEALTH SCIENCES

# PU`EGA O GAOIOIGA

**Faatonuga:** Tusi mai le lisi mo gaoioiga mo le aso lea na mäfua ai ona mamafa ma fufusi lau mänava, e ese mai ai i lau mänava mäsani. Tusi mai le taimi tonu na amata ai gaoioiga ta`itasi i lea aso. Afai na e faia ni gaoioiga/faamälositino e lë o lisiina mai i lalo pe na e faia faalua se gaoioiga/faamalositino ona (toe) tusi mai lea i le 'Other/Repeat Activities' ma ia tusi i lalo le taimi na amata ai.

---

Mo gaoioiga o le aso ………………………….., ……./……./…….
Aso Masina Tausaga

Na fusi le masini i le ……. am/pm ma na ave`ese i le ……. taeao/afiafi.

| Gaoioiga | Taimi na amata ai | Gaoioiga | Taimi na amata ai |
|---|---|---|---|
| **Taaloga i le Polo** | | **Faamalositino** | |
| Paseketipolo/Netipolo | _____ am/pm | Aerobics exercise | _____ am/pm |
| Faatavalegäpolo (fafo/fale) | _____ am/pm | Uila vili vae | _____ am/pm |
| Kilikiti Pälagi | _____ am/pm | Siva | _____ am/pm |
| Tägäpolo | _____ am/pm | Faamälositino fale/`äiga | _____ am/pm |
| Lakapi | _____ am/pm | Fai Faato`aga/tuäfale | _____ am/pm |
| Soka | _____ am/pm | Kalate | _____ am/pm |
| Sofupolo | _____ am/pm | Tamo`emo`e i le alatele | _____ am/pm |
| Sikuosi | _____ am/pm | Savaliga Umi i le Vao | _____ am/pm |
| Tenisi | _____ am/pm | Savaliga i le alatele | _____ am/pm |
| **Gaoioiga Faa-Maori:** | | **Gaoioiga i le Vai/Sami:** | |
| Kapa haka | _____ am/pm | Fägota (I luga o Papa/Vai) | _____ am/pm |
| Taiaha | _____ am/pm | Alogäva`a /va`aalo | _____ am/pm |
| Mau rakau | _____ am/pm | `A`au | _____ am/pm |
| Waka | _____ am/pm | | |
| Kai moana | _____ am/pm | | |
| | _____ am/pm | **Nisi / Toe fai Gäoioiga:** | _____ am/pm |
| **Gaoioiga Faa-Pasefika :** | | ____________________ | _____ am/pm |
| Siva | _____ am/pm | ____________________ | _____ am/pm |
| Kirikiti | _____ am/pm | ____________________ | _____ am/pm |
| Alogäva`a (Va'aalo/paopao) | _____ am/pm | ____________________ | _____ am/pm |

**Office Use**

| Activity Code | SPARC Code | V/M/L | Duration | METs | Ave HR |
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## O Le Lisi Lona 1 - Taaloga/Faamälositino/Gaoioiga

| | | | |
|---|---|---|---|
| 1. | Aerobics | 30. | Softball |
| 2. | Aquarobics | 31. | Squash |
| 3. | Ta`aloga Afeleti - Athletics (track and field) | 32. | Faase`e/Surfing/body boarding |
| 4. | Badminton | 33. | Surf life saving |
| 5. | Pasiketipolo | 34. | `A`au |
| 6. | Faata`avalepolo i fafo/totonu o le fale | 35. | Tenisi/Tennis |
| 7. | Faata`avalega Polo i totonu o fale | 36. | Tramping |
| 8. | Kirikiti – i totonu o le fale | 37. | Triathlon |
| 9. | Kirikiti – i fafo | 38. | Volipolo/Volleyball |
| 10. | Uilavilivae – miliga | 39. | Ave va`afaila/sailing/dinghy sailing |
| 11. | Uilavilivae – recreational (not mountain biking | 40. | Savali toleni (10 - 30mins) |
| 12. | Faamalositino potopotoga/alu i le gym (isi mea ile gym ae le o le aerobics)/si'isi'i meamamafa | 41. | Savali toleni po'o enjoyment (>30mins) |
| 13. | Faamälositino i le fale | | |
| 14. | Fagota | | **Gaoioiga Fa'aMaori** |
| 15. | Faifato`aga | 42. | Kapa haka |
| 16. | Golf | 43. | Taiaha |
| 17. | Hockey | 44. | Mau rakau |
| 18. | Ti`eti`e Solofanua/Equestrian | 45. | Waka |
| 19. | Motor sports (motorcycling, trail biking, motor racing) | | |
| 20. | Uilavilivae i mauga/Mountain biking | 46. | Isi Itu`äiga (Tusi i lalo) |
| 21. | Netipolo/Netball | | |
| 22. | Alogävaa (le va`a) | | |
| 23. | Lakapi Iuni (Union) | | |
| 24. | Lakapi Liki (League) | | |
| 25. | Lakapi – Pa`i | | |
| 26. | Tamo`e/jogging/cross-country | | |
| 27. | Fanafanaga (rifle & pistol) | | |
| 28. | Faase`ega i le Kiona | | |
| 29. | Soka/Soccer | | |

**Gaoioiga mämä**: O gaoioiga e le mafua ai ona sela.
**Gaoioiga fa'afeoloolo**: O gaoioiga e mafua ai ona televave teisi le tätä o le fatu.
**Gaoioiga Titio**: O gaoioiga e mafua ai le ga`e ma faafaigata ona tautala i fuaiupu atoa ma le manava i le taimi e tasi.

## O Le Lisi Lona 2 – O Fealua'iga

| | |
|---|---|
| 1. | Savali |
| 2. | Uilavilivae[a] |
| 3. | Tamo`e |
| 4. | Isi ituaiga[b] |

a) E taulia le (tandem) uila e ave ai tagata e to`alua [recumbent or mountain bike to work.]
b) E taulia le roller-blading, non-motorised scooter, skateboarding, alogävaa (le va`a), Faase`ega i le kiona or ti`eti`e solofanua.

## O Le Lisi Lona 3 - O Galuega

| Mama | Faafeoloolo | Titio |
|---|---|---|
| Tagata su`i ofu | Fufulu fale mamafa | Si`isi`i mea mamafa |
| Faigaluega i le ofisa | Farming | Faigaluega i le togavao |
| Standing - bartending, store clerk, filing, photocopying | Machine tooling - operating lathe, punch press, drilling, welding | Tautu`ugä solofanua |
| Fufulu/Tapena fale | Fofo | Faufale mamafa/tele |
| Ave ta`avale/pasi (Fa`auli) | Sisi`i pusa mama | Eli Pu so`o |
| | Faifaatoaga | Tätä fafie [sawing wood] |
| | Plumbing | |
| | Plastering | |
| | Fai Eletise | |
| | Uelo Welding | |

## O Le Lisi Lona 4 – Cultural/O Isi Ituaiga Gaoioiga

| Cultural Activities | Gaoioiga i le fale | Galuega Tauofo |
|---|---|---|
| Cultural dance | Salu | Tä`a`alo ma tamaiti |
| Traditional games | Fufulu fale | Savali televave |
| | Mopping | Fufulu ma tapena le falesa |
| | Fai le veki | |
| | Si`iga o pusa/sifi fale | |
| | Kamuka | |
| | Vali fale, fai le wallpaper | |
| | All home repairs | |
| | Fai fa`atoaga | |
| | Moa le vao | |

**Tongan Translations**

Physical Activity Readiness Quesstionnaire
Instruction Sheet: Heart Rate Monitoring
Physical Activity Log
NZPAQ-LF Showcards

**Ngaahi fehu'I pe 'oku ke fe'unga ke kau he fekumi ki he fakamalohisino**
(ma'ae kakai ta'u 15 ki he 69)

Lau ke mahino 'a e ngaahi fehu'I pea tali totonu: tali 'IO pe 'IKAI.

| Io | Ikai | |
|---|---|---|
| ☐ | ☐ | 1. Kuo fakaha atu nai 'e ho'o toketa 'oku palopalema ho mafu pea keke fai pe 'a e ngaue pe fakamalohision tene tala atu? |
| ☐ | ☐ | 2. 'Oku alanga ho fatafata 'iha taimi 'oku ke fai ai ha ngaue? |
| ☐ | ☐ | 3. Na'e langa nai ho fatafata he mahina kuo 'osi 'I ha'o nofo pe ta'e fai ha me'a? |
| ☐ | ☐ | 4. Kuo mole nai ho'o palanisi 'I ha'o ninimo pe ne 'ikai nai keke toe 'ilo ha me'a? |
| ☐ | ☐ | 5. 'Oku 'iai ha palopalema ho hui pe hokotanga hui 'oku pehe 'e toe kovi ange ka fakalahi ho'o ngauengaue? |
| ☐ | ☐ | 6. 'Oku lolotonga 'oatu 'e he toketaa ha'o fo'i'akau ki ha'o toto ma'olunga pe mahaki mafu? |
| ☐ | ☐ | 7. 'Oku ke toe 'ilo'I ha ngaahi 'uhinga kehe 'oku 'ikai ai ke totonu ke toe lahiange ho'o ngaue pe fakamalohision. |

Kuo 'osi lau, mahino'I peau tali e ngaahi fehu'i. Ko ha'aku ngaahi fehu'I kehe neu fiemalie ki he ngaahi tali na'e fai mai.

**Hingoa: ________________________________** **'Aho: _______________**

**Fakamo'oni: ______________________________**

**PEPA FAKAHINOHINO: LEKOOTI ‘O E TA ‘A E MAFU HE NGÄUE ‘OKU TE FAI**

‘E oatu e mita fua ho mafu, uesa uasi mo e ki’i pepa loka he ‘aho ‘e 3 ka hoko. Ko e ki’I pepa loka he ‘aho ‘e 3 ka hoko. Ko e ki’i mita ‘e fiema’u ia ke ke tui ma’u pë mei he taimi teke ‘a ai (hili ho’o kaukau) ‘o toki vete pë peake mohe. Ka’iai ha palopalema, kataki ‘o telefoni mai he vave taha ki he fika 3737599 va’a 86353.

## FAKAHINOHINO KI HONO NGÄUE’AKI ‘O E MITA

***Sitepu 1: Founga hono tui:***

1) ‘Osi ho’o tui e leta ki he ki’i mita pea ke tui leva. Fakatokanga’i ko e ki’i mita, ‘oku tohi’i ai e fo’i lea POLAR. Fakapapau’i ko e taimi teke tui ai ‘e tu’u ‘a e fo’ilea POLAR ‘I he vaeua malie ‘o e faha’i mata’u ho fatafata ‘i lala ho huhu (hufanga he fakatapu) pea hanga lelei ki mu’a.

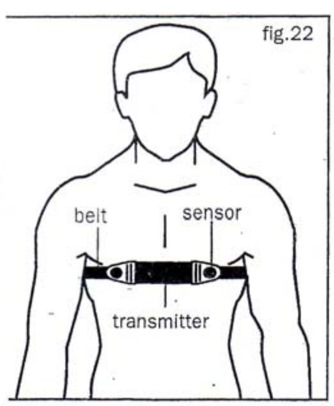
2) Tui e leta ‘o e ki’i mita pea ‘e lava pë keke ‘ai e leta ke loloa lelei pea fe’unga lelei mo koe he taimi teke tui ai.

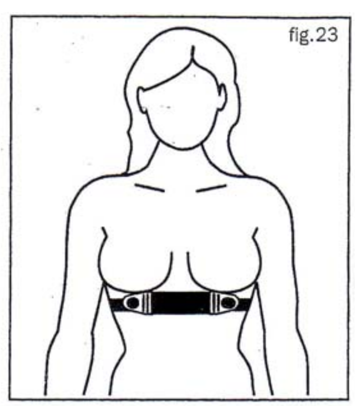
3) Ke ngäue lelei ‘a e ki’i mita (‘Ihe faha’i ki loto ‘o e mita ‘oku ‘iaia e ongo ki’i me’a faka’uhila ai he ongo tafa’aki. Ko e ongo me’a ni (‘oku na fotunga hangë ha pulu akapulu) ena ‘asi he leta. ‘E lava ‘o ngäue lelei ‘a e mita kapau teke unu ho tuhu ‘iha vai pea ke valivali ‘aki ‘a e ongo ki’I konga ko’eni kimu’a pea ke toki tui e ki’i mita.

4) ‘Oku ‘iai mo e uasi keke tui. Fakatonga’i he uasi ‘oku ‘iai e me’a pë konga lanu kulokula ai. Ko ho’o tui pë mita ki he mafu pea ke lomi’I e me’a kulokula he uasi pea e kamata leva ‘ene lekooti ‘a e ta ho mafu ‘i loto pë he sekoni ‘e 15.-

<u>Palopalema - Kapau he’ikai lekooti e ta ho mafu.</u>

- Toe fai pë me’a tatau he ngaahi sitepu, pea fakapapau’i na’e viku lelei pë ‘elia na’a ke vali ‘aki e vai.
- To e fakapapau’I ‘oku tokoto pë fa’aki lelei e ongo me’a ‘oku ‘iai e ‘uhila ki ho kili pea ‘oku ma’u lelei ‘a e ki’I mita ho’o tui.



***Sitepu 2: Founga hono lekooti ''o e ta e mafu:***

5) Lomi'I e ki'i fo'i ki he tafa'aki mata'u 'o e uasi 'oku 'iai e ki'i t fakahinohino 'oku tuhu ki lalo ( ⇩ ) kae oua leva keke sio 'oku 'asi mai he uasi e fo'i lea ko e TIME (pë Taimi).
6) Ko e kamata lekooti 'a e ta ho mafu, lomi'i 'a e fo'i ki lanu kulokula he ua… (kae 'oleva kuo ke fanongo ki he ki'i le'o piipi mei he uasi) Vakai'I ne kamata totonu mo e uasi foki.
7) Kapau he'ikai lekooti lelei 'a e ta ho mafu, teke fakatokanga'I 'a e ki'I maama 'e ulo fakatafa'aki he tafa'aki mata'u ho uasi pea e lelelele hokohoko pë ia he 'aho kotoa.
8) Tui ma'u pë uasi pea fakapapau'I 'e mama'o 'aki ma'u pë 'a e mita 'e 1 mei he ki'I mita ki he mafu.

Palopalema: Ngaahi me'a 'e Ala Hoko .

- Kapau ko e "00" e fika e lau mei he mita ki he mafu, 'oku 'iai e palopalema 'oku hoko tupu 'I he ngaahi 'uhinga ko'eni:
  - Kau Noa:'Oku 'iai e ngaahi me'a kehe 'oku kau noa he ngäue 'a e mita hangë ko e komipiuta, fotokopi, vekiume mo e ngaahi naunau pehee. 'E lava pë ke toe lekooti lelei pë ngäue lelei 'a e mita ni kapau teke mavahe koe ke mama'o mei he ngaahi misini.
  - Fe'unu'aki 'a e leta 'o e mita: Fakapapau'I 'oku nofo lelei e leta.
  - Pakupaku e ongo konga faka'uhila: Vakai'I pë na'e fe'unga pë me'I vai na'e faka viku 'aki.

- Kapau 'e hili e palopalema pea toe lekooti lelei pë mita, fakapapau'I na'a ke toe seti fo'ou e uasi 'aki ho'o lomi'I e fo'I ki 'e tu'u ai e ngäue 'a e uasi (Fo'I ki he faha'I hema ki lalo 'o e uasi) pea ke toe foki pë 'o kamata mai mei he sitepu 5.

To'o e uasi moe mita 'o tuku fakalelei kimu'a pea ke mohe. Ka toe kamata e lekooti, tui e ki'I mita pea fakahanga ki ai e uasi 'I he sekoni 'e 5.

Ko ho'o 'a'ahi hono 2 'e fai he ……………..'ihe……….Pongipongi pë efiafi

Ko ho'o 'a'ahi hono 3 'e fai he …..…………'ihe ………Pongipongi pë efiafi

THE UNIVERSITY OF AUCKLAND
FACULTY OF MEDICAL AND HEALTH SCIENCES

# LOKA PE FOOMU KI HE NGAUE'I 'O E SINO

**Fakahinohino:** Hiki 'a e kotoa 'o e ngaahi ngaue na'a ke fai he 'aho ni neke hele'ia ange ai mei he anga maheni. Ko e fo'I ngaue kotoape he 'aho ni, hki 'a e taimi totonu na'a ke kamata ai e ngaue. Kapau na'a ke fai ha ngaue 'o lahi ange he tu'o taha kataki 'o hiki ia 'I he konga 'o e foomu 'oku fakalea 'o pehe ngaahi me'a ki he /hiki tu'o ua.

---

Ko eku ngaahi ngaue 'eni ………………………….., ……./……./…….
Aho mahina Ta'u

Na'a ku 'a he 'aho ni he …….pongipongi/efiafi pea naa'ku mohe he …….pongipongi/efiafi.

| Ngaue | Taimi Kamata 'o e ngaue | Ngaue | Taimi Kamata 'o e ngaue |
|---|---|---|---|
| **Va'inga mo e Pulu** | | **Ngaahi Fakamalohisino** | |
| Pasiketipolo/Netipolo | _____ pongipongi/efifafi | Fakamalohisino Fasi | _____ pongipongi/efifafi |
| Tekapulu | _____ pongipongi/efiafi | Aka Pasikala | _____ pongipongi/efifafi |
| Kilikiti (Faka Palangi) | _____ pongipongi/efiafi | Tauolunga | _____ pongipongi/efifafi |
| Tapulu | _____ pongipongi/efifafi | Fakamalohisino (simi/api) | _____ pongipongi/efifafi |
| Akapulu | _____ pongipongi/efifafi | Ngoue | _____ pongipongi/efifafi |
| Soka | _____ pongipongi/efifafi | Kalate | _____ pongipongi/efifafi |
| Sofipolo | _____ pongipongi/efifafi | Lele/toto | _____ pongipongi/efifafi |
| Sikuasi | _____ pongipongi/efifafi | Alu Kemi he vao | _____ pongipongi/efifafi |
| Tenisi | _____ pongipongi/efifafi | Luelue | pongipongi/efifafi |
| **Ngaue Faka Mauli:** | | **Ngaue 'ihe Vai:** | |
| Kapa haka | _____ pongipongi/efifafi | Taumata'u (Rock, River) | _____ pongipongi/efifafi |
| Taiaha | _____ pongipongi/efifafi | 'A'alo (Kayak, Canoe) | _____ pongipongi/efifafi |
| Mau rakau | _____ pongipongi/efifafi | Kakau | _____ pongipongi/efifafi |
| Waka | _____ pongipongi/efifafi | | |
| Kai moana | _____ pongipongi/efifafi | **Ngaahi Me'akai Kehe/Hiki tu'o Ua:** | |
| | | ____________________ | _____ pongipongi/efifafi |
| **Ngaue Faka Pasifiki:** | | ____________________ | _____ pongipongi/efifafi |
| Tau'olunga Faka Pasifiki | _____ pongipongi/efifafi | ____________________ | _____ pongipongi/efifafi |
| Kilikiti Faka Pasifiki | _____ pongipongi/efifafi | ____________________ | _____ pongipongi/efifafi |
| 'A'alo Popao | _____ pongipongi/efifafi | ____________________ | _____ pongipongi/efifafi |

**Office Use**

| Activity Code | SPARC Code | V/M/L | Duration | METs | Ave HR |
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## Kaati Fakahinohino 1: Sipoti mo e ngaahi fakamalohisino kehe

| | | | |
|---|---|---|---|
| 1. | Fakamalohisino eulopiki | 30. | Sofipolo |
| 2. | Va'inga he vai | 31. | Sikuasi |
| 3. | Sipoti lele | 32. | Fanifo |
| 4. | Petiminitohi | 33. | Kakau Fakahaofi Mo'ui |
| 5. | Pasiketipolo | 34. | Kakau |
| 6. | Tekapulu ‘i Tu'a | 35. | Tenisi |
| 7. | Tekapulu ‘i Fale | 36. | ‘Alu Kemi he Vao |
| 8. | Kilikiti ‘i Tu'a | 37. | Tulaiefiloni |
| 9. | Kilikiti ‘i Fale | 38. | Volipolo |
| 10. | Lova pasikala | 39. | Folau ‘Iote |
| 11. | Aka Pasikala (Fakamalohision) | 40. | Lue fakamalohisino pë fiefia (Miniti 10 – 30) |
| 12. | Kalasi Fakamalohisino ngäue'aki fale fakamalohision, hiki me'amamafa | 41. | Lue fakamalohisino pë fiefia (Lahi he miniti 30) |
| 13. | Fakamalohisino ‘i ‘Api | | Ngaahi Ouau Faka-Mauli |
| 14. | Taumata'u | 42. | Kapahaka |
| 15. | Ngoue | 43. | Taiaha |
| 16. | Ta Pulu | 44. | Mau rakau |
| 17. | Hoki | 45. | Waka |
| 18. | Heka Hoosi | 46. | Ngaahi me'a kehe (Hiki Heni) |
| 19. | Lova ka | | |
| 20. | Heika paiki he mo'unga | | |
| 21. | Netipolo | | |
| 22. | ‘A'alo | | |
| 23. | ‘Akapulu Iunioni | | |
| 24. | ‘Akapulu Liiki | | |
| 25. | Aleapulu malemale | | |
| 26. | Lele, Totoo, Lele Kolosi Fonua | | |
| 27. | Fana (Laifolo pë pekenene) | | |
| 28. | Sikii | | |
| 29. | Soka | | |

**Ngäue Ma'ama'a:** Ngäue ma'ama'a ‘oku ‘ikai keke hela ai pë mei ‘osi e manava.
**Ngäue Mafamafa:** Ngäue ‘e ‘ilonga ai ha hohoo ‘a e manava pea ta vave e mafu.
**Ngäue Mamafa:** Ngäue ‘oku fu'u hela'ia, hohoo e manava pea mo faingata'a ‘o ikai tau lelei e manava.

## Kaati Fakahinohino 2: Fetu' utaki

| | |
|---|---|
| 1. | Luelue |
| 2. | Akapasikala |
| 3. | Lele |
| 4. | Ngäue Kehe |

a) Ko e heka pasikala 'oku kau ai 'a e heka he pasikala tokoua pë pasikala loua pea 'aka pasikala he mo'unga ki he ngäue.
b) Ko e ngaahi me'a kehe ko e 'alu he sikeiti pë sikuta ta'e misini, sikeitipooti, 'a'alo vaka, sikii, pë heka hoosi.

## Kaati Fakahinohino 3: Ngäue'anga

| Ngäue Ma'ama'a | Ngäue Lahi | Ngäue Mamafa |
|---|---|---|
| Tuitui | Ngäue Kilina mamafa | Hiki me'amamafa |
| Ngäue 'Ofisi | Faama | Naue Vaotata |
| Ngäue Tu'u – Le'o , Kalake Faile, Tauhikoloa, paaki pepa | Ngäue Misini hangë ko e vili, kasa, fufulu me'alele | Lova Hoosi |
| Kilina | Fotofota | Ngäue Langa |
| Faka'uli | Ngäue Hiki Me'a | Keli Luo |
| Komipiuta | Ngoue | Ta'akau pë kili 'akau |
| | Palama | |
| | Palasita | |
| | Ngäue 'Uhila | |
| | Kasa | |

## Kaati Fakahinohino 4: Ngäue Fakafonua pë Ngäue Kehe

| Ouau Fakafonua | Ngäue Faka'api | Ngäue'ofa |
|---|---|---|
| Tau'olunga Fakafonua | Tafi | Va'inga mo e fanau |
| Va'inga Fakafonua | Kilina | Luelue |
| | Mopi | Fakama'a 'Api Siasi |
| | Vekiume | |
| | Hiki Puha | |
| | Tufunga | |
| | Vali | |
| | Monomono 'Api | |
| | Ngoue | |
| | Huo 'Api | |

**Kaati Fakahinohino 5: Ngäue Ma'ama'a 'Aupito**

| Fakatata `o e Ngaahi Ngäue |
|---|
| Sio TV pë Faiva |
| Nofo noa |
| Tokoto aa he mohenga |
| Fanongo hiva |
| Lautohi |
| Telefoni |
| Metiaite |
| Lotu Tu'ulutui |
| Tohi |
| T'u Laine |
| Pasese me'alele |

**Kaati Fakahinohino 6: Tu'unga Faka-sosale mo Faka-'ekonomika**

| | | | |
|---|---|---|---|
| 01 | Ikai ha Pa'anga Humai | 08 | \$30,001 - \$40,000 |
| 02 | \$1,000 - \$5,000 | 09 | \$40,001 - \$50,000 |
| 03 | \$5,001 - \$10,000 | 10 | \$50,001 - \$70,000 |
| 04 | \$10,001 - \$15,000 | 11 | \$70,001 - \$100,000 |
| 05 | \$15,001 - \$20,000 | 12 | \$100,000 pë lahi hake |
| 06 | \$20,001 - \$25,000 | 13 | Ta'eloto ke fakaha |
| 07 | \$25,001 - \$30,000 | | |

# APPENDIX B

## B1-4: NZPAQs vs. HRM
## Analyses 1-4 by Age, Ethnicity, and Gender

## B5-8: NZPAQ-SF vs. NZPAQ-LF
## Analyses 1-4 by Age, Ethnicity, and Gender

# APPENDIX B

1: NZPAQs vs. HRM
Analysis 1 by Age, Ethnicity, and Gender

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 1* by Age 18-39 yrs

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **HRM N=62** |
| Walking | 88.8 (39.7, 137.9) | 67.3 (27.5, 107.1) | 23.4 (9.8, 37.0) |
| Moderate | 178.4 (97.8, 259.0) | 331.8 (233.3, 430.3) | 93.4 (34.9, 151.9) |
| Vigorous | 110.2 (70.3, 150.1) | 106.0 (71.8, 140.2) | 62.3 (32.3, 92.3) |
| Total | 377.4 (251.0, 503.8) | 505.2 (384.4, 626.0) | 179.2 (118.0, 240.4) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.38, p = 0.002 | 0.43, p = 0.0005 | -- |
| Moderate | 0.25, p = 0.05 | 0.10, p = 0.45 | -- |
| Vigorous | 0.26, p = 0.004 | 0.39, p = 0.002 | -- |
| Total | 0.35, p = 0.006 | 0.28, p = 0.03 | -- |
| **Activity Category** | **% in Activity Categories (n=62)** | | |
| Relatively Inactive | 35.5 | 22.6 | 56.5 |
| Relatively Active | 21.0 | 21.0 | 22.6 |
| Highly Active | 43.6 | 56.5 | 21.0 |
| Weighted Kappa to HRM | 0.23 | 0.20 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 23.4 | 43.8 | 6.3 |
| ≥ 2.5 hours, < 5 days | 42.2 | 34.4 | 35.9 |
| Weighted Kappa vs. HRM | 0.29 | 0.16 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 1* by Age 40-59 yrs

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=59** |
| Walking | 117.7 (13.5, 221.9) | 63.1 (36.7, 89.5) | 22.4 (7.1, 37.7) |
| Moderate | 267.7 (116.6, 418.8) | 304.4 (199.5, 409.3) | 160.1 (85.2, 235.0) |
| Vigorous | 121.2 (67.0, 175.4) | 88.2 (56.3, 120.1) | 45.3 (10.3, 80.3) |
| Total | 506.6 (311.2, 702.0) | 455.7 (311.9, 579.5) | 227.8 (139.7, 315.9) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.15, p = 0.25 | 0.43, p = 0.0006 | -- |
| Moderate | 0.05, p = 0.74 | 0.03, p = 0.80 | -- |
| Vigorous | 0.28, p = 0.03 | 0.21, p = 0.11 | -- |
| Total | 0.24, p = 0.07 | 0.19, p = 0.16 | -- |
| **Activity Category** | **% in Activity Categories (n=59)** | | |
| Relatively Inactive | 27.1 | 27.1 | 55.9 |
| Relatively Active | 27.1 | 22.0 | 20.3 |
| Highly Active | 45.8 | 50.9 | 23.7 |
| Weighted Kappa to HRM | 0.19 | 0.13 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 36.7 | 40.0 | 5.0 |
| ≥ 2.5 hrs, < 5 days | 36.7 | 33.3 | 38.3 |
| Weighted Kappa vs. HRM | 0.10 | 0.06 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 1* by Age 60+ yrs

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=62** | **NZPAQ-LF N=62** | **HRM N=59** |
| Walking | 162.5 (110.8, 214.2) | 136.3 (91.4, 181.2) | 50.2 (18.3, 82.1) |
| Moderate | 371.3 (158.6, 584.0) | 304.0 (188.8, 419.2) | 91.3 (39.2, 143.4) |
| Vigorous | 84.5 (50.8, 118.2) | 43.1 (18.8, 67.4) | 31.6 (201, 61.1) |
| Total | 619.3 (397.5, 841.1) | 483.4 (351.1, 615.7) | 173.1 (102.0, 244.2) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.29, p = 0.02 | 0.45, p = 0.0003 | **--** |
| Moderate | -0.03, p = 0.80 | -0.13, p = 0.32 | **--** |
| Vigorous | 0.28, p = 0.03 | 0.33, p = 0.01 | **--** |
| Total | 0.09, p = 0.48 | 0.05, p = 0.69 | **--** |
| **Activity Category** | **% in Activity Categories (n=59)** | | |
| Relatively Inactive | 20.3 | 25.4 | 64.4 |
| Relatively Active | 17.0 | 20.3 | 18.6 |
| Highly Active | 62.7 | 54.2 | 16.7 |
| Weighted Kappa vs. HRM | 0.06 | 0.06 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 45.2 | 45.2 | 4.8 |
| ≥ 2.5 hours, < 5 days | 35.5 | 30.7 | 29.0 |
| Weighted Kappa vs. HRM | 0.02 | 0.08 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 1* by Ethnicity: European/Other

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=57** |
| Walking | 129.4 (75.3, 183.5) | 120.6 (74.5, 166.7) | 60.6 (28.0, 93.2) |
| Moderate | 276.3 (60.4, 492.2) | 298.0 (204.2, 391.8) | 163.1 ( 84.0, 242.2) |
| Vigorous | 108.4 (70.0, 146.8) | 105.5 (70.3, 140.7) | 92.4 (47.5, 137.3) |
| Total | 514.0 (286.4, 741.6) | 524.1 (414.3, 633.9) | 316.0 (228.5, 403.5) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.36, p = 0.006 | 0.53, p < 0.0001 | -- |
| Moderate | 0.17, p = 0.21 | 0.23, p = 0.086 | -- |
| Vigorous | 0.38, p = 0.004 | 0.49, p = 0.0001 | -- |
| Total | 0.34, p = 0.011 | 0.37, p = 0.005 | -- |
| **Activity Category** | **% in Activity Categories (n=57)** | | |
| Relatively Inactive | 19.3 | 8.8 | 40.4 |
| Relatively Active | 22.8 | 28.1 | 19.3 |
| Highly Active | 57.9 | 63.2 | 40.4 |
| Weighted Kappa to HRM | 0.27 | 0.24 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 36.7 | 51.7 | 10.0 |
| ≥ 2.5 hours, < 5 days | 45.0 | 40.0 | 46.7 |
| Weighted Kappa vs. HRM | 0.20 | 0.16 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 1* by Ethnicity: Maori

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=61** | **NZPAQ-LF N=61** | **HRM N=58** |
| Walking | 83.8 (52.0, 115.6) | 56.0 (30.4, 81.6) | 20.5 (4.9, 36.1) |
| Moderate | 239.5 (121.7, 357.3) | 365.1 (247.1, 483.1) | 144.4 (69.7, 219.1) |
| Vigorous | 80.4 (45.9, 114.9) | 79.0 (52.1, 105.9) | 30.2 (4.6, 55.8) |
| Total | 403.7 (276.8, 530.6) | 500.1 (363.8, 636.4) | 195.4 (109.3, 281.5) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.11, p = 0.42 | 0.31, p = 0.02 | -- |
| Moderate | 0.09, p = 0.49 | -0.08, p = 0.57 | -- |
| Vigorous | 0.16, p = 0.22 | 0.19, p = 0.15 | -- |
| Total | 0.13, p = 0.31 | 0.10, p = 0.46 | -- |
| **Activity Category** | **% in Activity Categories (n=58)** | | |
| Relatively Inactive | 29.3 | 29.3 | 62.1 |
| Relatively Active | 22.4 | 15.5 | 22.4 |
| Highly Active | 48.3 | 55.2 | 15.5 |
| Weighted Kappa to HRM | 0.07 | 0.08 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 32.8 | 39.3 | 6.6 |
| ≥ 2.5 hours, < 5 days | 39.3 | 32.8 | 29.5 |
| Weighted Kappa vs. HRM | 0.03 | 0.09 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 1* by Ethnicity: Pacific

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=65** | **NZPAQ-LF N=65** | **HRM N=65** |
| Walking | 153.1 (49.9, 256.3) | 90.7 (50.1, 131.3) | 16.5 (4.4, 28.6) |
| Moderate | 297.2 (170.9, 423.5) | 279.9 (175.6, 384.2) | 45.5 (24.5, 66.5) |
| Vigorous | 126.4 (74.0, 178.8) | 55.4 (25.4, 85.4) | 21.3 (2.8, 39.8) |
| Total | 576.7 (388.8, 764.6) | 426.0 (298.5, 553.5) | 83.3 (56.0, 110.6) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.25, p = 0.04 | 0.33, p = 0.01 | -- |
| Moderate | 0.05, p = 0.70 | -0.18, p = 0.15 | -- |
| Vigorous | 0.23, p = 0.06 | 0.27, p = 0.03 | -- |
| Total | 0.15, p = 0.23 | -0.02, p = 0.86 | -- |
| **Activity Category** | **% in Activity Categories** | | |
| Relatively Inactive | 33.9 | 35.4 | 72.3 |
| Relatively Active | 20.0 | 20.0 | 20.0 |
| Highly Active | 46.2 | 44.6 | 7.7 |
| Weighted Kappa to HRM | 0.05 | -0.03 | -- |
| **Current NZ Guidelines**[6] | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 35.4 | 38.5 | 0.0 |
| ≥ 2.5 hours, < 5 days | 30.8 | 26.2 | 27.7 |
| Weighted Kappa vs. HRM | X | X | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.
X = unable to calculate statistically

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 1* by Gender

| | **Mean minutes (95% CI) of activity over last 7 days** | | | | | |
|---|---|---|---|---|---|---|
| | **Male n = 90** | | | **Female n = 96** | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM n=87** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM n=93** |
| Walking | 157.4 (79.3, 235.5) | 96.0 (61.7, 130.3) | 23.0 (10.0, 36.0) | 90.1 (58.1, 122.1) | 82.3 (53.1, 111.5) | 40.2 (19.6, 60.8) |
| Spearman's r, p-value | 0.29 p = 0.0058 | 0.40 p = 0.0001 | -- | 0.26 p = 0.0134 | 0.46 p < 0.0001 | -- |
| Moderate | 347.2 (186.2, 508.2) | 386.3 (277.9, 494.7) | 135.6 (76.7, 194.5) | 200.6 (112.2, 289.0) | 245.6 (187.6, 303.6) | 94.9 (53.7, 136.1) |
| Spearman's r, p-value | 0.09 p = 0.4255 | 0.05 p = 0.6715 | -- | 0.05 p = 0.6190 | -0.01 p = 0.9330 | -- |
| Vigorous | 150.3 (104.4, 196.2) | 107.6 (75.9, 139.3) | 64.7 (34.9, 94.5) | 63.5 (45.3, 81.7) | 52.8 (36.2, 69.4) | 29.7 (9.5, 49.9) |
| Spearman's r, p-value | 0.26 p = 0.0153 | 0.37 p = 0.0005 | -- | 0.20 p = 0.0512 | 0.22 p = 0.0357 | -- |
| Total | 655.0 (469.1, 840.9) | 589.9 (463.1, 716.7) | 223.4 (156.4, 290.4) | 354.2 (249.6, 458.8) | 380.7 (312.1, 449.3) | 164.8 (113.7, 215.9) |
| Spearman's r, p-value | 0.14 p = 0.1993 | 0.21 p = 0.0568 | -- | 0.17 p = 0.1130 | 0.13 p = 0.2022 | -- |
| **Activity Category** | **% in Activity Categories** | | | | | |
| | **n=87** | | | **n=93** | | |
| Relatively Inactive | 21.8 | 23.0 | 52.9 | 33.3 | 26.9 | 64.5 |
| Relatively Active | 14.9 | 18.4 | 25.3 | 28.0 | 23.7 | 16.1 |
| Highly Active | 63.2 | 58.6 | 21.8 | 38.7 | 49.5 | 19.4 |
| Wtd Kappa vs. HRM | 0.16 | 0.11 | -- | 0.13 | 0.14 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | | | | |
| ≥ 2.5 hours, ≥ 5 days | 36.8 | 44.8 | 5.8 | 31.2 | 39.8 | 5.4 |
| ≥ 2.5 hours, < 5 days | 41.4 | 32.2 | 41.4 | 35.5 | 33.3 | 30.1 |
| Wtd Kappa vs. HRM | 0.12 | 0.08 | -- | 0.12 | 0.12 | -- |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.
SF = NZPAQ-SF, LF = NZPAQ-LF

# APPENDIX B

2: NZPAQs vs. HRM
Analysis 2 by Age, Ethnicity, and Gender

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 2* by Age 18-39 yrs

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **HRM N=62** |
| Walking | 88.8 (39.7, 137.9) | 67.3 (27.5, 107.1) | 23.4 (9.8, 37.0) |
| Moderate | 178.4 (97.8, 259.0) | 331.8 (233.3, 430.3) | 93.4 (34.9, 151.9) |
| Vigorous | 220.4 (140.6, 300.2) | 212.0 (143.6, 280.4) | 124.6 (64.5, 184.7) |
| Total | 487.6 (338.7, 636.5) | 611.2 (466.2, 756.2) | 241.5 (165.0, 318.0) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.38, p = 0.002 | 0.43, p = 0.0005 | -- |
| Moderate | 0.25, p = 0.049 | 0.10, p = 0.45 | -- |
| Vigorous | 0.26, p = 0.04 | 0.38, p = 0.002 | -- |
| Total | 0.41, p = 0.001 | 0.29, p = 0.01 | -- |
| **Activity Category** | **% in Activity Categories (n=62)** | | |
| Relatively Inactive | 25.8 | 17.7 | 50.0 |
| Relatively Active | 22.6 | 21.0 | 21.0 |
| Highly Active | 51.6 | 61.3 | 29.0 |
| Weighted Kappa vs. HRM | 0.31 | 0.23 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations (n=62)** | | |
| ≥ 2.5 hours, ≥ 5 days | 22.6 | 43.6 | 6.5 |
| ≥ 2.5 hours, < 5 days | 51.6 | 38.7 | 43.6 |
| Weighted Kappa vs. HRM | 0.30 | 0.16 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 2* by Age 40-59 yrs

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=59** |
| Walking | 117.7 (13.5, 221.9) | 63.1 (36.7, 89.5) | 22.4 (7.1, 37.7) |
| Moderate | 267.7 (116.6, 418.8) | 304.4 (199.5, 409.3) | 160.1 (85.2, 235.0) |
| Vigorous | 242.3 (113.9, 350.7) | 176.4 (112.6, 240.2) | 90.6 (20.6, 160.6) |
| Total | 627.8 (400.9, 854.7) | 543.8 (402.0, 685.6) | 273.1 (167.5, 378.7) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.15, p = 0.26 | 0.43, p = 0.001 | -- |
| Moderate | 0.05, p = 0.74 | 0.03, p = 0.80 | -- |
| Vigorous | 0.28, p = 0.03 | 0.21, p = 0.11 | -- |
| Total | 0.30, p = 0.02 | 0.26, p = 0.04 | -- |
| **Activity Category** | **% in Activity Categories (n=59)** | | |
| Relatively Inactive | 22.0 | 25.4 | 55.9 |
| Relatively Active | 27.1 | 22.0 | 17.0 |
| Highly Active | 50.9 | 52.5 | 27.1 |
| Weighted Kappa vs. HRM | 0.25 | 0.20 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations (n=59)** | | |
| ≥ 2.5 hours, ≥ 5 days | 39.0 | 39.0 | 5.1 |
| ≥ 2.5 hours, < 5 days | 39.0 | 36.0 | 39.0 |
| Weighted Kappa vs. HRM | 0.09 | 0.09 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 2* by Age 60+ yrs

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=62** | **NZPAQ-LF N=62** | **HRM N=59** |
| Walking | 162.5 (110.8, 214.2) | 136.3 (91.4, 181.2) | 50.2 (18.3, 82.1) |
| Moderate | 371.3 (158.6, 584.0) | 304.0 (188.8, 419.2) | 91.3 (39.2, 143.4) |
| Vigorous | 170.9 (103.5, 238.3) | 86.3 (37.6, 135.0) | 63.1 (4.1, 122.1) |
| Total | 704.8 (476.0, 933.6) | 526.6 (380.8, 672.4) | 204.6 (118.6, 290.6) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.29, p = 0.02 | 0.45, p = 0.0003 | -- |
| Moderate | -0.03, p = 0.80 | -0.13, p = 0.32 | -- |
| Vigorous | 0.28, p = 0.03 | 0.33, p = 0.01 | -- |
| Total | 0.11, p = 0.41 | 0.04, p = 0.58 | -- |
| **Activity Category** | **% in Activity Categories (n=59)** | | |
| Relatively Inactive | 17.0 | 24.2 | 64.4 |
| Relatively Active | 15.3 | 16.1 | 15.3 |
| Highly Active | 67.8 | 59.7 | 20.3 |
| Weighted Kappa vs. HRM | 0.04 | 0.03 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations (n=59)** | | |
| ≥ 2.5 hours, ≥ 5 days | 42.4 | 17.7 | 5.1 |
| ≥ 2.5 hours, < 5 days | 40.7 | 30.7 | 30.5 |
| Weighted Kappa vs. HRM | 0.01 | 0.10 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 2* by Ethnicity: European/Other

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=57** |
| Walking | 129.4 (75.3, 183.5) | 120.6 (74.5, 166.7) | 60.6 (28.0, 93.2) |
| Moderate | 276.3 (60.4, 492.2) | 298.0 (204.2, 391.8) | 163.1 (84.0, 242.2) |
| Vigorous | 216.7 (139.9, 293.5) | 211.0 (140.6, 281.4) | 184.7 (94.9, 274.5) |
| Total | 622.4 (391.8, 853.0) | 629.6 (501.9, 757.3) | 408.4 (299.9, 516.9) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.36, p = 0.006 | 0.53, p < 0.0001 | -- |
| Moderate | 0.17, p = 0.21 | 0.23, p = 0.09 | -- |
| Vigorous | 0.38, p = 0.004 | 0.49, p = 0.0001 | -- |
| Total | 0.36, p = 0.006 | 0.41, p =0.002 | -- |
| **Activity Category** | **% in Activity Categories (n=57)** | | |
| Relatively Inactive | 8.8 | 7.0 | 40.4 |
| Relatively Active | 24.6 | 24.6 | 8.8 |
| Highly Active | 66.7 | 68.4 | 50.9 |
| Weighted Kappa vs. HRM | 0.25 | 0.25 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations (n=57)** | | |
| ≥ 2.5 hours, ≥ 5 days | 38.6 | 50.9 | 10.5 |
| ≥ 2.5 hours, < 5 days | 52.6 | 42.1 | 49.1 |
| Weighted Kappa vs. HRM | 0.11 | 0.17 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 2* by Ethnicity: Maori

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=61** | **NZPAQ-LF N=61** | **HRM N=58** |
| Walking | 83.8 (52.0, 115.6) | 56.0 (30.4, 81.6) | 20.9 (5.2, 36.6) |
| Moderate | 239.5 (121.7, 357.3) | 365.1 (247.1, 483.1) | 144.4 (69.7, 219.1) |
| Vigorous | 160.8 (91.7, 229.9) | 158.1 (104.3, 211.9) | 60.4 (9.2, 111.6) |
| Total | 484.1 (343.1, 625.1) | 579.2 (425.0, 733.4) | 225.6 (129.0, 322.2) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.11, p = 0.42 | 0.31, p = 0.02 | -- |
| Moderate | 0.09, p =0.49 | -0.08, p = 0.57 | -- |
| Vigorous | 0.16, p = 0.22 | 0.19, p = 0.15 | -- |
| Total | 0.22, p = 0.09 | 0.15, p = 0.26 | -- |
| **Activity Category** | **% in Activity Categories (n=58)** | | |
| Relatively Inactive | 25.9 | 29.3 | 56.9 |
| Relatively Active | 22.4 | 10.3 | 22.4 |
| Highly Active | 51.7 | 60.3 | 20.7 |
| Weighted Kappa vs. HRM | 0.11 | 0.10 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations (n=58)** | | |
| ≥ 2.5 hours, ≥ 5 days | 29.3 | 37.9 | 6.9 |
| ≥ 2.5 hours, < 5 days | 44.8 | 32.8 | 36.2 |
| Weighted Kappa vs. HRM | 0.05 | 0.10 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 2* by Ethnicity: Pacific

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=65** | **NZPAQ-LF N=65** | **HRM N=65** |
| Walking | 153.1 (49.9, 256.3) | 90.7 (50.1, 131.3) | 16.5 (4.4, 28.6) |
| Moderate | 297.2 (170.9, 423.5) | 279.9 (175.6, 384.2) | 45.5 (24.5, 66.5) |
| Vigorous | 252.8 (147.9, 357.7) | 110.8 (50.9, 170.7) | 42.5 (5.5, 79.5) |
| Total | 703.1 (479.2, 927.0) | 481.4 (334.4, 628.4) | 104.6 (64.1, 145.1) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.25, p = 0.04 | 0.33, p = 0.007 | -- |
| Moderate | 0.05, p = 0.70 | -0.18, p = 0.15 | -- |
| Vigorous | 0.23, p = 0.06 | 0.27, p = 0.03 | -- |
| Total | 0.20, p = 0.12 | 0.04, p = 0.77 | -- |
| **Activity Category** | **% in Activity Categories** | | |
| Relatively Inactive | 29.2 | 30.8 | 70.8 |
| Relatively Active | 18.5 | 23.1 | 21.5 |
| Highly Active | 52.3 | 46.2 | 7.7 |
| Weighted Kappa vs. HRM | 0.11 | 0.02 | -- |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 35.4 | 38.5 | 0.0 |
| ≥ 2.5 hours, < 5 days | 35.4 | 30.8 | 29.2 |
| Weighted Kappa vs. HRM | X | X | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 2* by Gender

| | **Mean minutes (95% CI) of activity over last 7 days** | | | | | |
|---|---|---|---|---|---|---|
| | **Male n = 90** | | | **Female n = 96** | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM n=87** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM n=93** |
| Walking | 157.5 (79.4, 235.5) | 96.0 (61.7, 130.3) | 23.0 (10.0, 36.0) | 90.1 (58.1, 122.1) | 82.3 (53.1, 111.5) | 40.2 (19.6, 60.8) |
| Spearman's r, p-value | 0.29 p = 0.0058 | 0.40 p = 0.0001 | -- | 0.26 p = 0.0134 | 0.46 p < 0.0001 | -- |
| Moderate | 347.2 (186.2, 508.2) | 386.3 (277.9, 494.7) | 135.6 (76.7, 194.5) | 200.6 (112.2, 289.0) | 245.6 (187.6, 303.6) | 94.9 (53.7, 136.1) |
| Spearman's r, p-value | 0.09 p = 0.4255 | 0.05 p = 0.6715 | -- | 0.05 p = 0.6190 | -0.01 p = 0.9330 | -- |
| Vigorous | 300.6 (208.7, 392.5) | 215.2 (151.9, 278.5) | 129.5 (69.9, 189.1) | 127.0 (90.6, 163.4) | 105.5 (72.4, 138.6) | 59.5 (19.1, 99.9) |
| Spearman's r, p-value | 0.26 p = 0.0153 | 0.37 p = 0.0005 | -- | 0.20 p = 0.0512 | 0.22 p = 0.0357 | -- |
| Total | 805.3 (599.1, 1011.5) | 697.5 (550.7, 844.3) | 288.1 (205.5, 370.7) | 417.7 (308.8, 526.6) | 433.5 (357.8, 509.2) | 194.6 (134.6, 254.6) |
| Spearman's r, p-value | 0.19 p = 0.0715 | 0.28 p = 0.0088 | -- | 0.22 p = 0.0326 | 0.18 p = 0.0841 | -- |
| **Activity Category** | **% in Activity Categories** | | | | | |
| | **n=87** | | | **n=93** | | |
| Relatively Inactive | 18.4 | 20.7 | 49.4 | 24.7 | 24.7 | 63.4 |
| Relatively Active | 12.6 | 18.4 | 18.4 | 30.1 | 20.4 | 17.2 |
| Highly Active | 69.0 | 60.9 | 32.2 | 45.2 | 54.8 | 19.4 |
| Wtd Kappa vs. HRM | 0.15 | 0.16 | -- | 0.19 | 0.15 | -- |
| **Current NZ Guidelines**[6] | **% Meeting Current Recommendations** | | | | | |
| ≥ 2.5 hours, ≥ 5 days | 36.8 | 44.8 | 5.8 | 32.3 | 39.8 | 5.4 |
| ≥ 2.5 hours, < 5 days | 44.8 | 34.5 | 44.8 | 43.0 | 35.5 | 31.2 |
| Wtd Kappa vs. HRM | 0.09 | 0.12 | -- | 0.14 | 0.12 | -- |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

# APPENDIX B

# 3: NZPAQs vs. HRM
# Analysis 3 by Age, Ethnicity, and Gender

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 3* by Age 18-39 yrs

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **HRM N=62** |
| Walking | 293.1 (131.1, 455.1) | 222.2 (91.0, 353.4) | 77.4 (32.4, 122.4) |
| Moderate | 713.8 (391.4, 1036.2) | 1327.0 (933.0, 1721.0) | 373.6 (139.5, 607.7) |
| Vigorous | 881.5 (562.3, 1200.7) | 848.1 (574.4, 1121.8) | 498.5 (258.3, 738.7) |
| Total | 1888.0 (1310.5, 2465.5) | 2398.0 (1821.5, 2974.5) | 949.5 (643.6, 1255.4) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.38, p = 0.002 | 0.43, p = 0.0005 | -- |
| Moderate | 0.25, p = 0.049 | 0.10, p = 0.45 | -- |
| Vigorous | 0.26, p = 0.043 | 0.39, p = 0.002 | -- |
| Total | 0.42, p = 0.001 | 0.34, p = 0.007 | -- |
| **Activity Category†** | **% in Activity Categories (n=62)** | | |
| Insufficiently Active | 45.2 | 41.9 | 82.3 |
| Sufficiently Active | 21.0 | 25.8 | 6.5 |
| Highly Active | 33.9 | 32.3 | 11.3 |
| Weighted Kappa vs. HRM | 0.20 | 0.19 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 3* by Age 40-59 yrs

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=59** |
| Walking | 388.5 (44.6, 732.4) | 208.2 (121.0, 295.4) | 74.0 (23.6, 124.4) |
| Moderate | 1071.0 (466.8, 1675.2) | 1218.0 (798.5, 1637.5) | 640.4 (340.6, 940.2) |
| Vigorous | 969.3 (535.6, 1403.0) | 705.5 (450.2, 960.8) | 362.4 (82.2, 642.6) |
| Total | 2429.0 (1544.6, 3313.4) | 2131.0 (1569.3, 2692.7) | 1077.0 (658.5, 1495.5) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.15, p = 0.26 | 0.43, p = 0.0006 | -- |
| Moderate | 0.05, p = 0.74 | 0.03, p = 0.80 | -- |
| Vigorous | 0.28, p = 0.03 | 0.21, p = 0.11 | -- |
| Total | 0.32, p = 0.01 | 0.26, p = 0.04 | -- |
| **Activity Category†** | **% in Activity Categories (n=59)** | | |
| Insufficiently Active | 40.7 | 44.0 | 86.4 |
| Sufficiently Active | 25.4 | 25.4 | 5.1 |
| Highly Active | 33.9 | 30.5 | 8.5 |
| Weighted Kappa vs. HRM | 0.09 | 0.04 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 3* by Age 60+ yrs

| | Mean MET-minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=62** | **NZPAQ-LF N=62** | **HRM N=59** |
| Walking | 536.4 (365.7, 707.1) | 449.9 (301.9, 598.0) | 165.6 (60.4, 270.8) |
| Moderate | 1485.0 (634.2, 2335.8) | 1216.0 (755.2, 1676.8) | 365.2 (157.0, 573.4) |
| Vigorous | 683.7 (414.1, 953.3) | 345.2 (150.4, 540.0) | 252.5 (16.3, 488.7) |
| Total | 2705.0 (1797.4, 3612.6) | 2011.0 (1435.0, 2587.0) | 783.3 (448.3, 1118.3) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.29, p = 0.02 | 0.45, p = 0.0003 | -- |
| Moderate | -0.03, p = 0.80 | -0.13, p = 0.32 | -- |
| Vigorous | 0.28, p = 0.03 | 0.33, p = 0.01 | -- |
| Total | 0.14, p = 0.29 | 0.07, p = 0.61 | -- |
| **Activity Category†** | **% in Activity Categories (n=59)** | | |
| Insufficiently Active | 37.9 | 44.1 | 91.5 |
| Sufficiently Active | 25.4 | 25.4 | 0.0 |
| Highly Active | 37.3 | 30.5 | 8.5 |
| Weighted Kappa vs. HRM | -- | -- | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 3* by Ethnicity: European/Other

| | Mean MET-minutes (± SD) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=57** |
| Walking | 427.0 (248.4, 605.6) | 397.9 (245.8, 550.0) | 199.9 (92.2, 307.6) |
| Moderate | 1105.0 (241.4, 1968.6) | 1192.0 (816.7, 1567.3) | 652.4 (336.2, 968.6) |
| Vigorous | 866.8 (559.6, 1174.0) | 844.0 (562.4, 1125.6) | 738.9 (379.9, 1097.9) |
| Total | 2399.0 (1487.6, 3310.4) | 2434.0 (1928.7, 2939.3) | 1591.0 (1160.1, 2022.0) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.36, p = 0.006 | 0.53, p < 0.0001 | -- |
| Moderate | 0.17, p = 0.21 | 0.23, p = 0.09 | -- |
| Vigorous | 0.38, p = 0.004 | 0.49, p = 0.0001 | -- |
| Total | 0.38, p = 0.004 | 0.40, p = 0.002 | -- |
| **Activity Category†** | **% in Activity Categories (n=57)** | | |
| Insufficiently Active | 33.3 | 26.3 | 79.0 |
| Sufficiently Active | 33.3 | 36.8 | 1.8 |
| Highly Active | 33.3 | 36.8 | 19.3 |
| Weighted Kappa vs. HRM | 0.12 | 0.20 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 3* by Ethnicity: Maori

| | **Mean MET-minutes (± SD) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=61** | **NZPAQ-LF N=61** | **HRM N=58** |
| Walking | 276.6 (171.5, 381.7) | 184.9 (100.6, 269.2) | 68.8 (16.9, 120.7) |
| Moderate | 958.0 (486.7, 1429.3) | 1460.0 (988.0, 1932.0) | 577.5 (279.0, 876.0) |
| Vigorous | 643.0 (366.7, 919.3) | 632.3 (417.1, 847.5) | 241.5 (36.6, 446.4) |
| Total | 1878.0 (1317.9, 2438.1) | 2277.0 (1662.9, 2891.1) | 887.8 (505.9, 1269.7) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.11, p = 0.42 | 0.31, p = 0.02 | -- |
| Moderate | 0.09, p = 0.49 | -0.08, p = 0.57 | -- |
| Vigorous | 0.16, p = 0.22 | 0.19, p = 0.15 | -- |
| Total | 0.24, p = 0.06 | 0.16, p = 0.24 | -- |
| **Activity Category†** | **% in Activity Categories (n=58)** | | |
| Insufficiently Active | 44.8 | 50.0 | 86.2 |
| Sufficiently Active | 22.4 | 20.7 | 5.2 |
| Highly Active | 32.8 | 29.3 | 8.6 |
| Weighted Kappa vs. HRM | 0.11 | 0.11 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 3* by Ethnicity: Pacific

| | Mean MET-minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=65** | **NZPAQ-LF N=65** | **HRM N=65** |
| Walking | 505.1 (164.7, 845.5) | 299.3 (165.3, 433.3) | 54.6 (14.7, 94.5) |
| Moderate | 1189.0 (683.6, 1694.4) | 1120.0 (702.8, 1537.2) | 181.9 (97.7, 266.1) |
| Vigorous | 1011.0 (591.4, 1430.6) | 443.1 (203.5, 682.7) | 170.2 ( 22.2, 318.2) |
| Total | 2705.0 (1836.4, 3573.6) | 1862.0 (1281.2, 2442.8) | 406.6 (245.9, 567.3) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.25, p = 0.04 | 0.33, p = 0.007 | -- |
| Moderate | 0.05, p = 0.70 | -0.18, p = 0.15 | -- |
| Vigorous | 0.23, p = 0.06 | 0.27, p = 0.03 | -- |
| Total | 0.20, p = 0.11 | 0.03, p = 0.82 | -- |
| **Activity Category†** | **% in Activity Categories (n=65)** | | |
| Insufficiently Active | 44.6 | 52.3 | 93.9 |
| Sufficiently Active | 16.9 | 20.0 | 4.6 |
| Highly Active | 38.5 | 27.7 | 1.5 |
| Weighted Kappa vs. HRM | 0.05 | -0.01 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 3* by Gender

| | Mean minutes (95% CI) of activity over last 7 days | | | | | |
|---|---|---|---|---|---|---|
| | Male n = 90 | | | Female n = 96 | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM n=87** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM n=93** |
| Walking | 519.7 (262.1, 777.3) | 316.9 (203.7, 430.1) | 75.9 (33.1, 118.7) | 297.4 (191.8, 403.3) | 271.7 (175.2, 368.2) | 132.6 (64.7, 200.5) |
| Spearman's r, p-value | 0.29 p = 0.0058 | 0.40 p = 0.0001 | -- | 0.26 p = 0.0134 | 0.46 p < 0.0001 | -- |
| Moderate | 1389.0 (745.0, 2033.0) | 1545.0 (1111.3, 1978.7) | 524.5 (288.8, 760.2) | 802.3 (448.8, 1155.8) | 982.5 (750.5, 1214.5) | 379.6 (214.9, 544.3) |
| Spearman's r, p-value | 0.09 p = 0.4255 | 0.05 p = 0.6715 | -- | 0.05 p = 0.6190 | -0.01 p = 0.9330 | -- |
| Vigorous | 1202.0 (834.5, 1569.5) | 860.9 (607.6, 1114.2) | 517.8 (279.4, 756.2) | 507.9 (362.3, 653.5) | 422.2 (289.6, 554.8) | 238.0 (76.2, 399.8) |
| Spearman's r, p-value | 0.26 p = 0.0153 | 0.37 p = 0.0005 | -- | 0.20 p = 0.0512 | 0.22 p = 0.0357 | -- |
| Total | 3111.0 (2300.1, 3921.9) | 2723.0 (2138.9, 3307.1) | 1136.0 (806.9, 1465.1) | 1608.0 (1183.7, 2032.3) | 1676.0 (1379.3, 1972.7) | 750.2 (516.4, 984.0) |
| Spearman's r, p-value | 0.21 p = 0.0543 | 0.29 p = 0.0068 | -- | 0.23 p = 0.0236 | 0.17 p = 0.0980 | -- |
| **Activity Category** | **% in Activity Categories** | | | | | |
| | **n=87** | | | **n=93** | | |
| Insufficiently Active | 34.5 | 39.1 | 85.1 | 47.3 | 47.3 | 88.2 |
| Sufficiently Active | 25.3 | 23.0 | 3.5 | 22.6 | 28.0 | 4.3 |
| Highly Active | 40.2 | 37.9 | 11.5 | 30.1 | 24.7 | 7.5 |
| Weighted Kappa vs. HRM | 0.08 | 0.10 | -- | 0.10 | 0.15 | -- |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

# APPENDIX B

## 4: NZPAQs vs. HRM
## Analysis 4 by Age, Ethnicity, and Gender

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 4* by Age 18-39 yrs

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **HRM N=62** |
| Walking | 399.3 (193.4, 605.2) | 277.7 (132.7, 422.7) | 113.9 (39.8, 188.0) |
| Moderate | 998.8 (579.4, 1418.2) | 1878.0 (1289.3, 2466.7) | 551.2 (221.2, 891.2) |
| Vigorous | 1291.0 (803.9, 1778.1) | 1181.0 (776.3, 1585.7) | 610.6 (333.6, 887.6) |
| Total | 2689.0 (1869.5, 3508.5) | 3336.0 (2479.5, 4192.5) | 1276.0 (880.7, 1671.3) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.37, p = 0.003 | 0.42, p = 0.0007 | -- |
| Moderate | 0.31, p = 0.01 | 0.14, p = 0.27 | -- |
| Vigorous | 0.24, p = 0.06 | 0.36, p = 0.004 | -- |
| Total | 0.43, p = 0.0004 | 0.35, p = 0.005 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups (n=62)** | | |
| < 1050 kcals/week | 40.6 | 23.4 | 60.9 |
| 1050-2099 kcals/week | 15.6 | 25.0 | 20.3 |
| ≥ 2100 kcals/week | 43.8 | 51.6 | 18.8 |
| Weighted Kappa vs. HRM | 0.32 | 0.20 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 4* by Age 40-59 yrs

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=59** |
| Walking | 572.2 (49.7, 1094.7) | 311.3 (167.9, 454.7) | 109.4 (33.0, 185.8) |
| Moderate | 1679.0 (683.3, 2674.7) | 1812.0 (1131.6, 2492.4) | 973.8 (501.5, 1446.1) |
| Vigorous | 1469.0 (727.1, 2210.9) | 1000.0 (631.8, 1368.2) | 468.8 (101.9, 835.7) |
| Total | 3720.0 (2153.2, 5286.8) | 3124.0 (2204.5, 4043.5) | 1552.0 (936.8, 2167.2) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.14, p = 0.28 | 0.40, p = 0.002 | -- |
| Moderate | 0.04, p = 0.79 | 0.01, p = 0.96 | -- |
| Vigorous | 0.27, p = 0.04 | 0.20, p = 0.13 | -- |
| Total | 0.29, p = 0.03 | 0.21, p = 0.11 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups (n=59)** | | |
| < 1050 kcals/week | 30.0 | 31.7 | 60.0 |
| 1050-2099 kcals/week | 23.3 | 16.7 | 20.0 |
| ≥ 2100 kcals/week | 46.7 | 51.7 | 20.0 |
| Weighted Kappa vs. HRM | 0.25 | 0.17 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 4* by Age 60+ yrs

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=62** | **NZPAQ-LF N=62** | **HRM N=60** |
| Walking | 784.5 (515.4, 1053.6) | 651.7 (420.8, 882.6) | 208.1 (81.1, 335.1) |
| Moderate | 2129.0 (890.4, 3367.6) | 1772.0 (1053.4, 2490.6) | 464.6 (212.1, 716.7) |
| Vigorous | 960.8 (550.6, 1371.0) | 483.2 (201.4, 765.0) | 306.1 (30.8, 581.4) |
| Total | 3874.0 (2514.9, 5233.1) | 2907.0 (2008.4, 3805.6) | 978.8 (590.1, 1367.5) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.24, p = 0.07 | 0.41, p = 0.001 | -- |
| Moderate | -0.03, p = 0.85 | -0.16, p = 0.24 | -- |
| Vigorous | 0.29, p = 0.03 | 0.32, p = 0.01 | -- |
| Total | 0.08, p = 0.53 | 0.04, p = 0.79 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups (n=60)** | | |
| < 1050 kcals/week | 22.6 | 30.7 | 74.2 |
| 1050-2099 kcals/week | 30.7 | 24.2 | 11.3 |
| ≥ 2100 kcals/week | 46.8 | 45.2 | 14.5 |
| Weighted Kappa vs. HRM | 0.01 | 0.03 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 4* by Ethnicity: European/Other

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **HRM N=57** |
| Walking | 531.9 (312.4, 751.4) | 480.1 (307.5, 652.7) | 232.7 (113.4, 352.0) |
| Moderate | 1427.0 (228.9, 2625.1) | 1478.0 (991.2, 1964.8) | 829.0 (417.6, 1240.4) |
| Vigorous | 1059.0 (671.1, 1446.9) | 1073.0 (687.4, 1458.6) | 846.2 (444.4, 1248.0) |
| Total | 3018.0 (1770.8, 4265.2) | 3032.0 (2332.9, 3731.1) | 1908.0 (1396.9, 2419.1) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.34, p = 0.01 | 0.50, p < 0.0001 | -- |
| Moderate | 0.21, p = 0.11 | 0.23, p = 0.09 | -- |
| Vigorous | 0.39, p = 0.003 | 0.46, p = 0.0003 | -- |
| Total | 0.40, p = 0.002 | 0.41, p = 0.001 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | |
| < 1050 kcals/week | 21.7 | 15.0 | 50.0 |
| 1050-2099 kcals/week | 36.7 | 30.0 | 18.3 |
| ≥ 2100 kcals/week | 41.7 | 55.0 | 31.7 |
| Weighted Kappa vs. HRM | 0.23 | 0.20 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 4* by Ethnicity: Maori

| | Mean activity energy expenditure in kcals/week (95% CI) over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=61** | **NZPAQ-LF N=61** | **HRM N=58** |
| Walking | 414.0 (251.1, 576.9) | 290.0 (149.0, 431.0) | 114.4 (26.1, 202.7) |
| Moderate | 1389.0 (720.0, 2058.0) | 2154.0 (1429.0, 2879.0) | 909.3 (433.2, 1385.4) |
| Vigorous | 992.6 (562.7, 1422.5) | 907.4 (595.5, 1219.3) | 350.5 (63.8, 637.2) |
| Total | 2796.0 (1958.6, 3633.4) | 3352.0 (2414.2, 4289.8) | 1374.0 (784.9, 1963.1) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.12, p = 0.37 | 0.32, p = 0.01 | -- |
| Moderate | 0.13, p = 0.33 | -0.05, p = 0.73 | -- |
| Vigorous | 0.17, p = 0.21 | 0.20, p = 0.13 | -- |
| Total | 0.32, p = 0.01 | 0.21, p = 0.11 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups (n=58)** | | |
| < 1050 kcals/week | 32.8 | 32.8 | 63.9 |
| 1050-2099 kcals/week | 23.0 | 13.1 | 19.7 |
| ≥ 2100 kcals/week | 44.3 | 54.1 | 16.4 |
| Weighted Kappa vs. HRM | 0.22 | 0.15 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 4* by Ethnicity: Pacific

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=65** | **NZPAQ-LF N=65** | **HRM N=65** |
| Walking | 790.1 (265.7, 1314.5) | 467.0 (249.9, 684.1) | 90.7 (17.8, 163.6) |
| Moderate | 1943.0 (1037.2, 2848.8) | 1826.0 (1101.3, 2550.7) | 293.1 (150.4, 435.8) |
| Vigorous | 1634.0 (890.1, 2377.9) | 705.0 (323.6, 1086.4) | 231.0 (33.1, 428.9) |
| Total | 4367.0 (2804.1, 5929.9) | 2998.0 (2010.0, 3986.0) | 614.8 (381.8, 847.8) |
| **Activity** | **Spearman's Correlation Coefficient (r) compared with HRM, p-value** | | |
| Walking | 0.24, p = 0.05 | 0.32, p = 0.009 | -- |
| Moderate | 0.07, p = 0.57 | -0.18, p = 0.15 | -- |
| Vigorous | 0.24, p = 0.049 | 0.25, p = 0.04 | -- |
| Total | 0.19, p = 0.14 | 0.02, p = 0.88 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | |
| < 1050 kcals/week | 38.5 | 36.9 | 80.0 |
| 1050-2099 kcals/week | 10.8 | 23.1 | 13.9 |
| ≥ 2100 kcals/week | 50.8 | 40.0 | 6.2 |
| Weighted Kappa vs. HRM | 0.08 | -0.02 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF and NZPAQ-LF vs. HRM:** Analysis 4* by Gender

| | Mean activity energy expenditure in kcals/week (95% CI) over last 7 days | | | | | |
|---|---|---|---|---|---|---|
| | Male<br>n = 90 | | | Female<br>n = 96 | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM<br>n=89** | **NZPAQ-SF** | **NZPAQ-LF** | **HRM<br>n=93** |
| Walking | 794.8<br>(398.5, 1191.1) | 490.2<br>(307.2, 673.2) | 121.6<br>(48.8, 194.4) | 385.4<br>(260.5, 510.2) | 341.0<br>(232.5, 449.5) | 161.0<br>(81.2, 240.8) |
| Spearman's r,<br>p-value | 0.28<br>p = 0.01 | 0.39<br>p = 0.0002 | -- | 0.20<br>p = 0.03 | 0.40<br>p < 0.0001 | -- |
| Moderate | 2165.0<br>(1169.2, 3160.8) | 2358.0<br>(1668.2, 3047.8) | 796.3<br>(440.7, 1151.9) | 1061.0<br>(590.7, 1531.3) | 1318.0<br>(987.3, 1648.7) | 493.5<br>(274.5, 712.5) |
| Spearman's r,<br>p-value | 0.09<br>p = 0.30 | 0.01<br>p = 0.77 | -- | 0.04<br>p = 0.52 | 0.01<br>p = 0.91 | -- |
| Vigorous | 1852.0<br>(1245.2, 2458.8) | 1276.0<br>(895.0, 1657.0) | 673.2<br>(365.8, 980.6) | 662.8<br>(461.6, 864.0) | 528.8<br>(365.9, 691.7) | 239.5<br>(77.2, 401.8) |
| Spearman's r,<br>p-value | 0.23<br>p = 0.03 | 0.33<br>p = 0.001 | -- | 0.19<br>p = 0.08 | 0.18<br>p = 0.08 | -- |
| Total | 4811.0<br>(3472.8, 6149.2) | 4124.0<br>(3193.7, 5054.3) | 1608.0<br>(1143.6, 2072.4) | 2109.0<br>(1541.5, 2676.5) | 2188.0<br>(1792.7, 2583.3) | 898.2<br>(624.5, 1171.9) |
| Spearman's r,<br>p-value | 0.18<br>p = 0.06 | 0.24<br>p = 0.01 | -- | 0.17<br>p = 0.07 | 0.07<br>p = 0.35 | -- |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | | | | |
| | **n=89** | | | **n=93** | | |
| < 1050 kcals/week | 22.2 | 23.3 | 55.6 | 39.6 | 33.3 | 74.0 |
| 1050-2099 kcals/week | 17.8 | 18.9 | 23.3 | 28.1 | 25.0 | 11.5 |
| ≥ 2100 kcals/week | 60.0 | 57.8 | 21.1 | 32.3 | 41.7 | 14.6 |
| Weighted Kappa vs. HRM | 0.15 | 0.15 | -- | 0.17 | 0.09 | -- |

*Total EE (kcals/week) calculated from equation on pg.103

# APPENDIX B

# 5: NZPAQ-SF vs. NZPAQ-LF
# Analysis 1 by Age, Ethnicity, and Gender

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 1* by Age 18-39 yrs

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **Spearman's r, p-value** |
| Walking | 88.8 (39.7, 137.9) | 67.3 (27.5, 107.1) | 0.44, p = 0.0003 |
| Moderate | 178.4 (97.8, 259.0) | 331.8 (233.3, 430.3) | 0.22, p = 0.08 |
| Vigorous | 110.2 (70.3, 150.1) | 106.0 (71.8, 140.2) | 0.47, p < 0.0001 |
| Total | 377.4 (251.0, 503.8) | 505.2 (384.4, 626.0) | 0.37, p = 0.003 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 34.4 | 21.9 | 0.39 |
| Relatively Active | 21.9 | 21.9 | |
| Highly Active | 43.8 | 56.3 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 23.4 | 43.8 | 0.41 |
| ≥ 2.5 hours, < 5 days | 42.2 | 34.4 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 1* by Age 40-59 yrs

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **Spearman's r, p-value** |
| Walking | 117.7 (13.5, 221.9) | 63.1 (36.7, 89.5) | 0.54, p < 0.0001 |
| Moderate | 267.7 (116.6, 418.8) | 304.4 (199.5, 409.3) | 0.29, p = 0.03 |
| Vigorous | 121.2 (67.0, 175.4) | 88.2 (56.3, 120.1) | 0.52, p < 0.0001 |
| Total | 506.6 (311.2, 702.0) | 455.7 (311.9, 579.5) | 0.55, p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 26.7 | 26.7 | 0.53 |
| Relatively Active | 26.7 | 21.7 | |
| Highly Active | 46.7 | 51.7 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 36.7 | 40.0 | 0.38 |
| ≥ 2.5 hours, < 5 days | 36.7 | 33.3 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 1* by Age 60+ yrs

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 162.5 (110.8, 214.2) | 136.3 (91.4, 181.2) | 0.73, p < 0.0001 |
| Moderate | 371.3 (158.6, 584.0) | 304.0 (188.8, 419.2) | 0.31, p = 0.01 |
| Vigorous | 84.5 (50.8, 118.2) | 43.1 (18.8, 67.4) | 0.55, p < 0.0001 |
| Total | 619.3 (397.5, 841.1) | 483.4 (351.1, 615.7) | 0.53, p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 19.4 | 24.2 | 0.36 |
| Relatively Active | 16.1 | 21.0 | |
| Highly Active | 64.5 | 54.8 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 45.2 | 45.2 | 0.40 |
| ≥ 2.5 hours, < 5 days | 35.5 | 30.7 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 1* by Ethnicity: European/Other

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **Spearman's r, p-value** |
| Walking | 129.4 (75.3, 183.5) | 120.6 (74.5, 166.7) | 0.55, p < 0.0001 |
| Moderate | 276.3 (60.4, 492.2) | 298.0 (204.2, 391.8) | 0.40, p = 0.002 |
| Vigorous | 108.4 (70.0, 146.8) | 105.5 (70.3, 140.7) | 0.57, p < 0.0001 |
| Total | 514.0 (286.4, 741.6) | 524.1 (414.3, 633.9) | 0.70, p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 18.3 | 8.3 | 0.46 |
| Relatively Active | 23.3 | 28.3 | |
| Highly Active | 58.3 | 63.3 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 36.7 | 51.7 | 0.39 |
| ≥ 2.5 hours, < 5 days | 45.0 | 40.0 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 1* by Ethnicity: Maori

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=61** | **NZPAQ-LF N=61** | **Spearman's r, p-value** |
| Walking | 83.8 (52.0, 115.6) | 56.0 (30.4, 81.6) | 0.60, p < 0.0001 |
| Moderate | 239.5 (121.7, 357.3) | 365.1 (247.1, 483.1) | 0.30, p = 0.02 |
| Vigorous | 80.4 (45.9, 114.9) | 79.0 (52.1, 105.9) | 0.69, p < 0.0001 |
| Total | 403.7 (276.8, 530.6) | 500.1 (363.8, 636.4) | 0.41, p = 0.001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 27.9 | 27.9 | 0.36 |
| Relatively Active | 21.3 | 16.4 | |
| Highly Active | 50.8 | 55.7 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 32.8 | 39.3 | 0.36 |
| ≥ 2.5 hours, < 5 days | 39.3 | 32.8 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 1* by Ethnicity: Pacific

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=65** | **NZPAQ-LF N=65** | **Spearman's r, p-value** |
| Walking | 153.1 (49.9, 256.3) | 90.7 (50.1, 131.3) | 0.62, p < 0.0001 |
| Moderate | 297.2 (170.9, 423.5) | 279.9 (175.6, 384.2) | 0.11, p = 0.41 |
| Vigorous | 126.4 (74.0, 178.8) | 55.4 (25.4, 85.4) | 0.40, p = 0.001 |
| Total | 576.7 (388.8, 764.6) | 426.0 (298.5, 553.5) | 0.44, p = 0.0003 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 33.9 | 35.4 | 0.42 |
| Relatively Active | 20.0 | 20.0 | |
| Highly Active | 46.2 | 44.6 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | |
| ≥ 2.5 hours, ≥ 5 days | 35.4 | 38.5 | 0.41 |
| ≥ 2.5 hours, < 5 days | 30.8 | 26.2 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 1* by Gender

| | Mean minutes (95% CI) of activity over last 7 days | | | | | |
|---|---|---|---|---|---|---|
| | Male n = 90 | | | Female n = 96 | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r, p-value** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r,** |
| Walking | 157.4 (79.3, 235.5) | 96.0 (61.7, 130.3) | 0.61 p < 0.0001 | 90.1 (58.1, 122.1) | 82.3 (53.1, 111.5) | 0.62 p < 0.0001 |
| Moderate | 347.2 (186.2, 508.2) | 386.3 (277.9, 494.7) | 0.29 p = 0.006 | 200.6 (112.2, 289.0) | 245.6 (187.6, 303.6) | 0.22 p = 0.03 |
| Vigorous | 150.3 (104.4, 196.2) | 107.6 (75.9, 139.3) | 0.53 p < 0.0001 | 63.5 (45.3, 81.7) | 52.8 (36.2, 69.4) | 0.45 p < 0.0001 |
| Total | 655.0 (469.1, 840.9) | 589.9 (463.1, 716.7) | 0.51 p < 0.0001 | 354.2 (249.6, 458.8) | 380.7 (312.1, 449.3) | 0.41 p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 21.1 | 22.2 | 0.49 | 32.3 | 26.0 | 0.35 |
| Relatively Active | 14.4 | 17.8 | | 28.1 | 25.0 | |
| Highly Active | 64.4 | 60.0 | | 39.6 | 49.0 | |
| **Current NZ Guidelines[6]** | **% Meeting Guidelines** | | **Weighted Kappa** | **% Meeting Guidelines** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 37.8 | 46.7 | 0.51 | 32.3 | 39.6 | 0.30 |
| ≥ 2.5 hours, < 5 days | 41.1 | 31.1 | | 35.4 | 34.4 | |

*Total minutes of brisk walking, moderate- and vigorous-intensity PA were simply summed.

# APPENDIX B

# 6: NZPAQ-SF vs. NZPAQ-LF
# Analysis 2 by Age, Ethnicity, and Gender

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 2* by Age 18-39 yrs

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 88.8 (39.7, 137.9) | 67.3 (27.5, 107.1) | 0.44, p = 0.44 |
| Moderate | 178.4 (97.8, 259.0) | 331.8 (233.3, 430.3) | 0.22, p = 0.08 |
| Vigorous | 220.4 (140.6, 300.2) | 212.0 (143.6, 280.4) | 0.48, p < 0.0001 |
| Total | 487.6 (338.7, 636.5) | 611.2 (466.2, 756.2) | 0.42, p = 0.0005 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 25.0 | 17.2 | 0.36 |
| Relatively Active | 23.4 | 20.3 | |
| Highly Active | 51.6 | 62.5 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 23.4 | 43.8 | 0.49 |
| ≥ 2.5 hours, < 5 days | 51.6 | 39.1 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 2* by Age 40-59 yrs

| | Mean minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 117.7 (13.5, 221.9) | 63.1 (36.7, 89.5) | 0.54, p < 0.0001 |
| Moderate | 267.7 (116.6, 418.8) | 304.4 (199.5, 409.3) | 0.29, p = 0.03 |
| Vigorous | 242.3 (113.9, 350.7) | 176.4 (112.6, 240.2) | 0.52, p < 0.0001 |
| Total | 627.8 (400.9, 854.7) | 543.8 (402.0, 685.6) | 0.57, p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 21.7 | 25.0 | 0.59 |
| Relatively Active | 26.7 | 21.7 | |
| Highly Active | 51.7 | 53.3 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 38.3 | 40.0 | 0.38 |
| ≥ 2.5 hours, < 5 days | 40.0 | 35.0 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 2* by Age 60+ yrs

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 162.5 (110.8, 214.2) | 136.3 (91.4, 181.2) | 0.73, p < 0.0001 |
| Moderate | 371.3 (158.6, 584.0) | 304.0 (188.8, 419.2) | 0.31, p = 0.01 |
| Vigorous | 170.9 (103.5, 238.3) | 86.3 (37.6, 135.0) | 0.55, p < 0.0001 |
| Total | 704.8 (476.0, 933.6) | 526.6 (380.8, 672.4) | 0.55, p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 16.1 | 24.2 | 0.37 |
| Relatively Active | 14.5 | 16.1 | |
| Highly Active | 69.4 | 59.7 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 45.2 | 45.2 | 0.39 |
| ≥ 2.5 hours, < 5 days | 38.7 | 30.7 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 2 by Ethnicity: European/Other

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 129.4 (75.3, 183.5) | 120.6 (74.5, 166.7) | 0.55, p < 0.0001 |
| Moderate | 276.3 (60.4, 492.2) | 298.0 (204.2, 391.8) | 0.40, p = 0.002 |
| Vigorous | 216.7 (139.9, 293.5) | 211.0 (140.6, 281.4) | 0.57, p < 0.0001 |
| Total | 622.4 (391.8, 853.0) | 629.6 (501.9, 757.3) | 0.76, p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 8.3 | 6.7 | 0.39 |
| Relatively Active | 25.0 | 23.3 | |
| Highly Active | 66.7 | 70.0 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 38.3 | 51.7 | 0.30 |
| ≥ 2.5 hours, < 5 days | 53.3 | 41.7 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 2* by Ethnicity: Maori

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 83.8 (52.0, 115.6) | 56.0 (30.4, 81.6) | 0.60, p < 0.0001 |
| Moderate | 239.5 (121.7, 357.3) | 365.1 (247.1, 483.1) | 0.30, p = 0.0196 |
| Vigorous | 160.8 (91.7, 229.9) | 158.1 (104.3, 211.9) | 0.69, p < 0.0001 |
| Total | 484.1 (343.1, 625.1) | 579.2 (425.0, 733.4) | 0.46, p = 0.0002 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 24.6 | 27.9 | 0.40 |
| Relatively Active | 21.3 | 11.5 | |
| Highly Active | 54.1 | 60.7 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 32.8 | 39.3 | 0.38 |
| ≥ 2.5 hours, < 5 days | 42.6 | 32.8 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 2* by Ethnicity: Pacific

| | **Mean minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 153.1 (49.9, 256.3) | 90.7 (50.1, 131.3) | 0.62, p < 0.0001 |
| Moderate | 297.2 (170.9, 423.5) | 279.9 (175.6, 384.2) | 0.11, p = 0.4051 |
| Vigorous | 252.8 (147.9, 357.7) | 110.8 (50.9, 170.7) | 0.40, p = 0.0010 |
| Total | 703.1 (479.2, 927.0) | 481.4 (334.4, 628.4) | 0.43, p = 0.0003 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 29.2 | 30.8 | 0.45 |
| Relatively Active | 18.5 | 23.1 | |
| Highly Active | 52.3 | 46.2 | |
| **Current NZ Guidelines[6]** | **% Meeting Current Recommendations** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 35.4 | 38.5 | 0.43 |
| ≥ 2.5 hours, < 5 days | 35.4 | 30.8 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 2* by Gender

| | Mean minutes (95% CI) of activity over last 7 days | | | | | |
|---|---|---|---|---|---|---|
| | **Male n = 90** | | | **Female n = 96** | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r, p-value** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r,** |
| Walking | 157.5 (79.4, 235.5) | 96.0 (61.7, 130.3) | 0.61 p < 0.0001 | 90.1 (58.1, 122.1) | 82.3 (53.1, 111.5) | 0.62 p < 0.0001 |
| Moderate | 347.2 (186.2, 508.2) | 386.3 (277.9, 494.7) | 0.29 p = 0.006 | 200.6 (112.2, 289.0) | 245.6 (187.6, 303.6) | 0.22 p = 0.03 |
| Vigorous | 300.6 (208.7, 392.5) | 215.2 (151.9, 278.5) | 0.53 p < 0.0001 | 127.0 (90.6, 163.4) | 105.5 (72.4, 138.6) | 0.45 p < 0.0001 |
| Total | 805.3 (599.1, 1011.5) | 697.5 (550.7, 844.3) | 0.52 p < 0.0001 | 417.7 (308.8, 526.6) | 433.5 (357.8, 509.2) | 0.44 p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 17.8 | 20.0 | 0.49 | 24.0 | 24.0 | 0.39 |
| Relatively Active | 12.2 | 17.8 | | 30.2 | 20.8 | |
| Highly Active | 70.0 | 62.2 | | 45.8 | 55.2 | |
| **Current NZ Guidelines[6]** | **% Meeting Guidelines** | | **Weighted Kappa** | **% Meeting Guidelines** | | **Weighted Kappa** |
| ≥ 2.5 hours, ≥ 5 days | 37.8 | 46.7 | 0.47 | 33.3 | 39.6 | 0.32 |
| ≥ 2.5 hours, < 5 days | 44.4 | 33.3 | | 42.7 | 36.5 | |

*Assumes 1 minute of vigorous-intensity = 2 minutes of moderate-intensity. Total minutes of brisk walking, moderate- and vigorous-intensity PA were summed.

# APPENDIX B

## 7: NZPAQ-SF vs. NZPAQ-LF
## Analysis 3 by Age, Ethnicity, and Gender

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 3* by Age 18-39 yrs

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 293.1 (131.1, 455.1) | 222.2 (91.0, 353.4) | 0.44, p = 0.0003 |
| Moderate | 713.8 (391.4, 1036.2) | 1327.0 (933.0, 1721.0) | 0.22, p = 0.08 |
| Vigorous | 881.5 (562.3, 1200.7) | 848.1 (574.4, 1121.8) | 0.48, p < 0.0001 |
| Total | 1888.0 (1310.5, 2465.5) | 2398.0 (1821.5, 2974.5) | 0.43, p = 0.0004 |
| **Activity Category†** | **% in Activity Categories** | | **Weighted Kappa** |
| Insufficiently Active | 43.8 | 40.6 | 0.29 |
| Sufficiently Active | 21.9 | 28.1 | |
| Highly Active | 34.4 | 31.3 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 3* by Age 40-59 yrs

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 388.5 (44.6, 732.4) | 208.2 (121.0, 295.4) | 0.54, p < 0.0001 |
| Moderate | 1071.0 (466.8, 1675.2) | 1218.0 (798.5, 1637.5) | 0.29, p = 0.03 |
| Vigorous | 969.3 (535.6, 1403.0) | 705.5 (450.2, 960.8) | 0.52, p < 0.0001 |
| Total | 2429.0 (1544.6, 3313.4) | 2131.0 (1569.3, 2692.7) | 0.57, p < 0.0001 |
| **Activity Category†** | **% in Activity Categories** | | **Weighted Kappa** |
| Insufficiently Active | 40.0 | 43.3 | 0.48 |
| Sufficiently Active | 25.0 | 26.7 | |
| Highly Active | 35.0 | 30.0 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 3* by Age 60+ yrs

| | Mean MET-minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 536.4 (365.7, 707.1) | 449.9 (301.9, 598.0) | 0.73, p < 0.0001 |
| Moderate | 1485.0 (634.2, 2335.8) | 1216.0 (755.2, 1676.8) | 0.31, p = 0.01 |
| Vigorous | 683.7 (414.1, 953.3) | 345.2 (150.4, 540.0) | 0.55, p < 0.0001 |
| Total | 2705.0 (1797.4, 3612.6) | 2011.0 (1435.0, 2587.0) | 0.53, p < 0.0001 |
| **Activity Category†** | **% in Activity Categories** | | **Weighted Kappa** |
| Insufficiently Active | 35.5 | 41.9 | 0.28 |
| Sufficiently Active | 24.2 | 27.4 | |
| Highly Active | 40.3 | 30.7 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 3 by Ethnicity: European/Other

| | Mean MET-minutes (95% CI) of activity over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 427.0 (248.4, 605.6) | 397.9 (245.8, 550.0) | 0.55, p < 0.0001 |
| Moderate | 1105.0 (241.4, 1968.6) | 1192.0 (816.7, 1567.3) | 0.40, p = 0.002 |
| Vigorous | 866.8 (559.6, 1174.0) | 844.0 (562.4, 1125.6) | 0.57, p < 0.0001 |
| Total | 2399.0 (1487.6, 3310.4) | 2434.0 (1928.7, 2939.3) | 0.75, p < 0.0001 |
| **Activity Category†** | **% in Activity Categories** | | **Weighted Kappa** |
| Insufficiently Active | 31.7 | 25.0 | 0.34 |
| Sufficiently Active | 33.3 | 40.0 | |
| Highly Active | 35.0 | 35.0 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 3* by Ethnicity: Maori

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 276.6 (171.5, 381.7) | 184.9 (100.6, 269.2) | 0.60, p < 0.0001 |
| Moderate | 958.0 (486.7, 1429.3) | 1460.0 (988.0, 1932.0) | 0.30, p = 0.02 |
| Vigorous | 643.0 (366.7, 919.3) | 632.3 (417.1, 847.5) | 0.69, p < 0.0001 |
| Total | 1878.0 (1317.9, 2438.1) | 2277.0 (1662.9, 2891.1) | 0.46, p = 0.0002 |
| **Activity Category†** | **% in Activity Categories** | | **Weighted Kappa** |
| Insufficiently Active | 42.6 | 47.5 | 0.25 |
| Sufficiently Active | 21.3 | 23.0 | |
| Highly Active | 36.1 | 29.5 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 3* by Ethnicity: Pacific

| | **Mean MET-minutes (95% CI) of activity over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 505.1 (164.7, 845.5) | 299.3 (165.3, 433.3) | 0.62, p < 0.0001 |
| Moderate | 1189.0 (683.6, 1694.4) | 1120.0 (702.8, 1537.2) | 0.11, p = 0.41 |
| Vigorous | 1011.0 (591.4, 1430.6) | 443.1 (203.5, 682.7) | 0.40, p = 0.001 |
| Total | 2705.0 (1836.4, 3573.6) | 1862.0 (1281.2, 2442.8) | 0.41, p = 0.0006 |
| **Activity Category†** | **% in Activity Categories** | | **Weighted Kappa** |
| Insufficiently Active | 44.6 | 52.3 | 0.42 |
| Sufficiently Active | 16.9 | 20.0 | |
| Highly Active | 38.5 | 27.7 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 3* by Gender

| | Mean MET-minutes (95% CI) of activity over last 7 days | | | | | |
|---|---|---|---|---|---|---|
| | **Male**<br>**n = 90** | | | **Female**<br>**n = 96** | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r, p-value** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r, p-value** |
| Walking | 519.7<br>(262.1, 777.3) | 316.9<br>(203.7, 430.1) | 0.61<br>p < 0.0001 | 297.4<br>(191.8, 403.3) | 271.7<br>(175.2, 368.2) | 0.62<br>p < 0.0001 |
| Moderate | 1389.0<br>(745.0, 2033.0) | 1545.0<br>(1111.3, 1978.7) | 0.29<br>p = 0.006 | 802.3<br>(448.8, 1155.8) | 982.5<br>(750.5, 1214.5) | 0.22<br>p = 0.03 |
| Vigorous | 1202.0<br>(834.5, 1569.5) | 860.9<br>(607.6, 1114.2) | 0.53<br>p < 0.0001 | 507.9<br>(362.3, 653.5) | 422.2<br>(289.6, 554.8) | 0.45<br>p < 0.0001 |
| Total | 3111.0<br>(2300.1, 3921.9) | 2723.0<br>(2138.9, 3307.1) | 0.51<br>p < 0.0001 | 1608.0<br>(1183.7, 2032.3) | 1676.0<br>(1379.3, 1972.7) | 0.43<br>p < 0.0001 |
| **Activity Category†** | **% in Activity Categories** | | **Weighted Kappa** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 33.3 | 37.8 | 0.39 | 45.8 | 45.8 | 0.29 |
| Relatively Active | 24.4 | 24.4 | | 22.9 | 30.2 | |
| Highly Active | 42.2 | 37.8 | | 31.3 | 24.0 | |

*Calculates total MET-minutes of PA over the last 7 days, †Activity categories defined on page 103

# APPENDIX B

# 8: NZPAQ-SF vs. NZPAQ-LF
# Analysis 4 by Age, Ethnicity, and Gender

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 4* by Age 18-39 yrs

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 399.3 (193.4, 605.2) | 277.7 (132.7, 422.7) | 0.43, p = 0.0004 |
| Moderate | 998.8 (579.4, 1418.2) | 1878.0 (1289.3, 2466.7) | 0.27, p = 0.03 |
| Vigorous | 1291.0 (803.9, 1778.1) | 1181.0 (776.3, 1585.7) | 0.51, p < 0.0001 |
| Total | 2689.0 (1869.5, 3508.5) | 3336.0 (2479.5, 4192.5) | 0.46, p = 0.0001 |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | **Weighted Kappa** |
| < 1050 kcals/week | 40.6 | 23.4 | 0.34 |
| 1050-2099 kcals/week | 15.6 | 25.0 | |
| > 2100 kcals/week | 43.8 | 51.6 | |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 4* by Age 40-59 yrs

| | **Mean activity energy expenditure in kcals/week (95% CI) over last 7 days** | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 572.2 (49.7, 1094.7) | 311.3 (167.9, 454.7) | 0.55, p < 0.0001 |
| Moderate | 1679.0 (683.3, 2674.7) | 1812.0 (1131.6, 2492.4) | 0.29, p = 0.0225 |
| Vigorous | 1469.0 (727.1, 2210.9) | 1000.0 (631.8, 1368.2) | 0.51, p < 0.0001 |
| Total | 3720.0 (2153.2, 5286.8) | 3124.0 (2204.5, 4043.5) | 0.53, p < 0.0001 |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | **Weighted Kappa** |
| < 1050 kcals/week | 30.0 | 31.7 | 0.53 |
| 1050-2099 kcals/week | 23.3 | 16.7 | |
| > 2100 kcals/week | 46.7 | 51.7 | |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 4* by Age 60+ yrs

| | Mean activity energy expenditure in kcals/week (95% CI) over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 784.5 (515.4, 1053.6) | 651.7 (420.8, 882.6) | 0.74, p < 0.0001 |
| Moderate | 2129.0 (890.4, 3367.6) | 1772.0 (1053.4, 2490.6) | 0.33, p = 0.01 |
| Vigorous | 960.8 (550.6, 1371.0) | 483.2 (201.4, 765.0) | 0.57, p < 0.0001 |
| Total | 3874.0 (2514.9, 5233.1) | 2907.0 (2008.4, 3805.6) | 0.57, p < 0.0001 |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | **Weighted Kappa** |
| < 1050 kcals/week | 22.6 | 30.7 | 0.46 |
| 1050-2099 kcals/week | 30.7 | 24.2 | |
| > 2100 kcals/week | 46.8 | 45.2 | |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 4* by Ethnicity: European/Other

| | Mean activity energy expenditure in kcals/week (95% CI) over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=60** | **NZPAQ-LF N=60** | **Spearman's r, p-value** |
| Walking | 531.9 (312.4, 751.4) | 480.1 (307.5, 652.7) | 0.57, p < 0.0001 |
| Moderate | 1427.0 (228.9, 2625.1) | 1478.0 (991.2, 1964.8) | 0.44, p = 0.0005 |
| Vigorous | 1059.0 (671.1, 1446.9) | 1073.0 (687.4, 1458.6) | 0.59, p < 0.0001 |
| Total | 3018.0 (1770.8, 4265.2) | 3032.0 (2332.9, 3731.1) | 0.78, p < 0.0001 |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | **Weighted Kappa** |
| < 1050 kcals/week | 21.7 | 15.0 | 0.55 |
| 1050-2099 kcals/week | 36.7 | 30.0 | |
| > 2100 kcals/week | 41.7 | 55.0 | |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 4* by Ethnicity: Maori

| | Mean activity energy expenditure in kcals/week (95% CI) over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 414.0 (251.1, 576.9) | 290.0 (149.0, 431.0) | 0.59, p < 0.0001 |
| Moderate | 1389.0 (720.0, 2058.0) | 2154.0 (1429.0, 2879.0) | 0.32, p = 0.011 |
| Vigorous | 992.6 (562.7, 1422.5) | 907.4 (595.5, 1219.3) | 0.70, p < 0.0001 |
| Total | 2796.0 (1958.6, 3633.4) | 3352.0 (2414.2, 4289.8) | 0.48, p < 0.0001 |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | **Weighted Kappa** |
| < 1050 kcals/week | 32.8 | 32.8 | 0.41 |
| 1050-2099 kcals/week | 23.0 | 13.1 | |
| > 2100 kcals/week | 44.3 | 54.1 | |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 4* by Ethnicity: Pacific

| | Mean activity energy expenditure in kcals/week (95% CI) over last 7 days | | |
|---|---|---|---|
| **Activity** | **NZPAQ-SF N=64** | **NZPAQ-LF N=64** | **Spearman's r, p-value** |
| Walking | 790.1 (265.7, 1314.5) | 467.0 (249.9, 684.1) | 0.64, p < 0.0001 |
| Moderate | 1943.0 (1037.2, 2848.8) | 1826.0 (1101.3, 2550.7) | 0.12, p = 0.34 |
| Vigorous | 1634.0 (890.1, 2377.9) | 705.0 (323.6, 1086.4) | 0.41, p = 0.0007 |
| Total | 4367.0 (2804.1, 5929.9) | 2998.0 (2010.0, 3986.0) | 0.44, p = 0.0003 |
| **Weekly Energy Expenditure** | **% in Energy Expenditure Groups** | | **Weighted Kappa** |
| < 1050 kcals/week | 38.5 | 36.9 | 0.37 |
| 1050-2099 kcals/week | 10.8 | 23.1 | |
| > 2100 kcals/week | 50.8 | 40.0 | |

*Total EE (kcals/week) calculated from equation on pg.103

**NZPAQ-SF vs. NZPAQ-LF:** Analysis 4* by Gender

| | Mean activity energy expenditure in kcals/week (95% CI) over last 7 days | | | | | |
|---|---|---|---|---|---|---|
| | **Male n = 90** | | | **Female n = 96** | | |
| **Activity** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r, p-value** | **NZPAQ-SF** | **NZPAQ-LF** | **Spearman's r, p-value** |
| Walking | 794.8 (398.5, 1191.1) | 490.2 (307.2, 673.2) | 0.61 p < 0.0001 | 385.4 (260.5, 510.2) | 341.0 (232.5, 449.5) | 0.62 p < 0.0001 |
| Moderate | 2165.0 (1169.2, 3160.8) | 2358.0 (1668.2, 3047.8) | 0.31 p = 0.003 | 1061.0 (590.7, 1531.3) | 1318.0 (987.3, 1648.7) | 0.25 p = 0.012 |
| Vigorous | 1852.0 (1245.2, 2458.8) | 1276.0 (895.0, 1657.0) | 0.55 p < 0.0001 | 662.8 (461.6, 864.0) | 528.8 (365.9, 691.7) | 0.44 p < 0.0001 |
| Total | 4811.0 (3472.8, 6149.2) | 4124.0 (3193.7, 5054.3) | 0.53 p < 0.0001 | 2109.0 (1541.5, 2676.5) | 2188.0 (1792.7, 2583.3) | 0.44 p < 0.0001 |
| **Activity Category** | **% in Activity Categories** | | **Weighted Kappa** | **% in Activity Categories** | | **Weighted Kappa** |
| Relatively Inactive | 22.2 | 23.3 | 0.46 | 39.6 | 33.3 | 0.39 |
| Relatively Active | 17.8 | 18.9 | | 28.1 | 25.0 | |
| Highly Active | 60.0 | 57.8 | | 32.3 | 41.7 | |

*Total EE (kcals/week) calculated from equation on pg.103

# APPENDIX C

## Participant Recall of Physical Activities

| SPORT/ RECREATION | PHYSICAL ACTIVITY | PA LOGS | NZPAQ-LF |
|---|---|---|---|
| 1 | Aerobics | 15 | 17 |
| 2 | Aqua aerobics | 2 | 4 |
| 3 | Athletics (track and field) | 0 | 0 |
| 4 | Badminton | 2 | 1 |
| 5 | Basketball | 5 | 4 |
| 6 | Bowls-outdoor/lawn | 2 | 3 |
| 7 | Bowls-indoor | 1 | 1 |
| 8 | Cricket – outdoors | 0 | 0 |
| 9 | Cricket – indoors | 0 | 0 |
| 10 | Cycling – competitive | 3 | 1 |
| 11 | Cycling – recreational (not mountain biking) | 1 | 6 |
| 12 | Exercise classes/going to the gym (other than aerobics work)/weight training | 30 | 34 |
| 13 | Exercising at home | 16 | 52 |
| 14 | Fishing | 0 | 2 |
| 15 | Gardening | 25 | 50 |
| 16 | Golf | 2 | 2 |
| 17 | Hockey | 0 | 0 |
| 18 | Horse riding/Equestrian | 2 | 2 |
| 19 | Motor sports (motorcycling, trail biking, motor racing) | 0 | 0 |
| 20 | Mountain biking | 0 | 0 |
| 21 | Netball | 0 | 2 |
| 22 | Rowing | 1 | 0 |
| 23 | Rugby Union | 2 | 2 |
| 24 | Rugby Leage | 0 | 1 |

| SPORT/ RECREATION | PHYSICAL ACTIVITY | PA LOGS | NZPAQ-LF |
|---|---|---|---|
| 25 | Rugby – Touch | 2 | 4 |
| 26 | Running/jogging/cross-country | 21 | 28 |
| 27 | Shooting (rifle & pistol) | 0 | 0 |
| 28 | Skiing | 0 | 0 |
| 29 | Soccer | 5 | 7 |
| 30 | Softball | 0 | 1 |
| 31 | Squash | 0 | 0 |
| 32 | Surfing/body boarding | 0 | 0 |
| 33 | Surf life saving | 0 | 0 |
| 34 | Swimming | 12 | 13 |
| 35 | Tennis | 2 | 3 |
| 36 | Tramping | 0 | 1 |
| 37 | Triathlon | 0 | 0 |
| 38 | Volleyball | 1 | 1 |
| 39 | Yachting/sailing/dinghy sailing | 0 | 1 |
| 40 | Walking for enjoyment or exercise (10-30min) | 42 | 50 |
| 41 | Walking for enjoyment or exercise (>30min) | 32 | 64 |
| 42 | Kapa haka | 11 | 20 |
| 43 | Taiaha | 4 | 8 |
| 44 | Mau Rakau | 0 | 4 |
| 45 | Waka | 0 | 0 |
| 46 | Martial Arts/Dancing | 2 | 16 |
| 47 | Yoga | 0 | 1 |
| 48 | Boxing | 1 | 0 |
| 49 | Kayaking | 1 | 3 |
| 50 | Other (trampoline, Petanque, table tennis) | 2 | 2 |

| TRANSPORT | PHYSICAL ACTIVITY | PA LOGS | NZPAQ-LF |
|---|---|---|---|
| 200 | Walking | 10 | 55 |
| 201 | Cycling | 0 | 0 |
| 202 | Running | 0 | 0 |
| 203 | Other | 1 | 0 |
| **OCCUPATION** | **PHYSICAL ACTIVITY** | **PA LOGS** | **NZPAQ-LF** |
| 300 | Carrying light loads | 2 | 7 |
| 301 | Moving/lifting light loads | 8 | 3 |
| 302 | Moving/lifting/carrying heavy loads | 12 | 13 |
| 303 | Walking | 15 | 11 |
| 304 | Heavy Cleaning | 0 | 1 |
| 305 | Light/Moderate Cleaning | 3 | 3 |
| 306 | Other (lawn mowing, planting) | 5 | 10 |
| **OTHER/ INCIDENTAL** | **PHYSICAL ACTIVITY** | **PA LOGS** | **NZPAQ-LF** |
| 400 | General cleaning | 29 | 104 |
| 401 | Walking - light, non-cleaning (ready to leave, shut/lock doors, close windows) | 14 | 0 |
| 402 | Painting (inside) | 1 | 3 |
| 403 | Self care | 13 | 0 |
| 404 | Moving furniture | 1 | 2 |
| 405 | Multiple household activities (moderate) | 4 | 0 |
| 406 | Lawn mowing | 3 | 3 |
| 407 | Playing with children | 4 | 44 |
| 408 | Carrying light to moderate loads | 4 | 2 |
| 409 | Carrying heavy loads | 5 | 2 |
| 410 | Home repair | 1 | 1 |
| 411 | Traditional game | 0 | 0 |

| OTHER/ INCIDENTAL | PHYSICAL ACTIVITY | PA LOGS | NZPAQ-LF |
|---|---|---|---|
| 412 | Childcare | 2 | 0 |
| 413 | Coaching sport | 1 | 0 |
| 414 | Emotion/Stress/Sport spectator | 0 | 0 |
| 415 | Socialising/eating | 15 | 0 |
| 416 | Religious/Church activity | 7 | 0 |
| 417 | Cultural Dance | 3 | 2 |
| 418 | Kitchen Activity - cooking, washing dishes | 10 | 0 |
| 419 | Clean/vacuum/tidy car | 0 | 0 |
| 420 | Cleaning church | 0 | 2 |
| 421 | Other (un/packing, non-church singing, shopping, playing instrument, laundry, auto repair, board games, caring for animals, take out rubbish) | 13 | 0 |
| 500 | Unknown | 61 | NA |