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Use of time and adolescent health-related quality of life/wellbeing: A scoping review

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Short title:

Time use and adolescent quality of life

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ABSTRACT

Time use could profoundly affect adolescents' health-related quality of life (HRQL). Ideally, overall time use patterns would be considered, because activities within a 24-hour day are inherently correlated (more in one activity means less in another). This review focused on the associations of 1) overall time use patterns and 2) components of time use patterns with HRQL in adolescents.

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Conclusion:

More physical activity, less screen time and more/adequate sleep, in isolation, are associated with better profile-based HRQL subscales. Greater understanding of adolescents' overall time use patterns and HRQL is a priority for policy development.

Keywords: Adolescent, lifestyle, quality of life, scoping review, time use

KEYNOTES

- Overall patterns of time use could profoundly affect adolescents' current and future health-related quality of life (HRQL).
- This review identified many studies examining specific aspects of time use and HRQL, with better outcomes associated with more physical activity, less screen time and more sleep/absence of sleep deprivation.
- Large-scale representative surveys are needed that incorporate valid measures of all major time use components simultaneously alongside utility- and profile-based HRQL.

INTRODUCTION

The 2016 Lancet commission has centred global attention on the health and wellbeing of adolescents (10-19 years) (1). Adolescence is typically considered a time of optimal health, yet it directly accounts for 35% of the global burden of disease, mostly from non-communicable diseases such as obesity and poor mental health (2). It is also a crucial transition phase (2, 3) when health patterns are established and track into adulthood (4).

How adolescents spend their time has been shown to impact on certain aspects of health (5). "Health" encompasses health status and functional status, as well as quality of life (6). Encompassed within quality of life is health-related quality of life (HRQL), i.e., quality of life in the context of one's health

and/or illness (7). HRQL can be used as an indicator to guide healthcare resource allocation (8), as it can be measured at the population level across all life stages. Therefore, it is important to understand whether potentially-modifiable time use patterns (i.e., general nature and timing of daily activities (5)) in adolescence are key determinants of HRQL.

Time use potentially has a bidirectional relationship with health: health influences time use, while time use can improve or reduce health. Current health promotion strategies recommend well-balanced lifestyles in children for optimal health (9, 10), but what a well-balanced lifestyle looks like for an adolescent remains unclear. A comprehensive insight into time use seems an essential prerequisite to designing targeted intervention programs to promote health-enhancing lifestyles (11).

To understand relationships between time use patterns and HRQL, both need to be reliably measured. Fortunately, such measures now exist. There are two main types of HRQL instruments: health profile and utility measures. Health profile measures have been widely available for the last two decades (12). They span multiple subdomains with good precision, but do not allow for calculation of quality-adjusted life years (QALYs) (6). Newer utility measures do produce QALYs but are shorter and have fewer items than health profile measures, reducing their sensitivity (13-15).

The two main types of time use measures are stylised analogues of time use diaries and 24-hour diaries. Stylised questions ask respondents to recall the habitual duration of relevant activities; they are widely used but often only cover a section of the day and are generally inaccurate (16). A 24-hour diary which records all activities over a 24-hour day either prospectively or retrospectively, is more accurate as it reduces social desirability bias and recall errors (17), and may consider activities' co-existence and displacement (5, 18). For example, high levels of physical activity and sedentary behaviour can co-exist, typically in "techno-active" boys who spend relatively large proportions of time on physical activity and screen time (19, 20).

Both types of measures can be analysed as components of time use in isolation (variable-centred) or in combination (person-centred) (21-23). A person-centred approach captures all activities an individual undertakes in a specified time period and explores them as a whole (21, 24). This requires complex data treatment and analysis to acknowledge the boundedness of time, i.e., that any increase in time spent in one activity necessarily decreases time in another (21, 24). In contrast, a variable-centred approach investigates one or more discrete activities in isolation, which are then typically analysed in simpler linear models, but does not acknowledge the finite nature of time and the necessary trade-offs (21, 24).

Adolescent time use patterns may present an opportunity to transform future health status (24-26). Thus, this scoping review aims to evaluate the associations of 1) person-centred time use and 2) variable-centred time use with HRQL in population-based studies involving 10 to 19 year olds.

METHODS

A preliminary scoping review in late 2015 informed the choice of search terms, databases and restrictions to be used. The search strategy was developed with a librarian expert in this area at the Royal Children's Hospital, Melbourne. Medline (Ovid), PsycINFO and Embase (Ovid) databases were searched in February 2016 using a common set of MeSH terms, thesaurus and/or keywords. PubMed was searched to retrieve yet-to-be indexed papers. Appendix 1 shows the Medline search strategy, which was then adapted for the other databases. Due to limited resources and the relative novelty of standardised time use and HRQL measurement in children, we restricted the review to papers published in English in the last twenty years.

Table 1 lists the inclusion and exclusion criteria. Data were extracted by a single author (MoW). Additional relevant articles were found by hand-searching reference lists of the identified articles and from experts in the field. From our prior knowledge, we did not expect a meta-analysis to be possible, so planned a scoping review (27). No formal quality rating was undertaken.

RESULTS

Figure 1 shows the progress to final inclusion of 29 articles. Only one article examined overall time use (i.e. person-centred) against a validated health profile HRQL measure (28); none used a utility HRQL measure. Therefore, we broadened the inclusion criteria for person-centred time use to include outcomes of wellbeing and functioning, identifying four further articles. An additional 24 articles examining individual activities (i.e. variable-centred) and HRQL were identified. As anticipated, time use instruments, HRQL constructs, data treatment and methodological decisions differed widely. Tables 2 and 3 present key information of the included studies, including type of time use measures (stylised vs 24-hour diary).

Person-centred time use (Table 2)

Relationships between HRQL and person-centred time use

Hunt's (28) cross-sectional community sample of 667 15-19 year olds was the only study to use a validated HRQL profile measure (the KIDSCREEN health profile measure (28, 29)) and a 24-hour time diary (table 2). Using latent profile models with their 31-item diary, they identified three probabilistic time use profiles in boys: i) 'productive', ii) 'high leisure', and iii) 'all-rounder'. Two profiles emerged in girls: i) 'higher study/lower leisure', and ii) 'moderate study/higher leisure'. There was no association between time use and HRQL in boys. In girls, 40% of those in the 'moderate study/higher leisure' group scored >0.5 standard deviations (SD) above the internal mean for HRQL, compared to 18% in the 'higher study/lower leisure' group (p=0.006). Of the many analyses conducted, only five associations were seen between HRQL subdomains and time use, and none remained significant after adjustment for multiple testing.

Relationships between wellbeing/functioning and person-centred time use

A further four American studies investigated person-centred time use against various questionnaires to measure different aspects of wellbeing/functioning (e.g. internalising and externalising problems, academic results, see Table 2) (30-33). Nelson's study (32) was the only one to measure an extensive

list of activities using a validated stylised questionnaire with a large national sample, while the other smaller studies used study-designed time use questionnaires (30, 33) and/or had a limited list of activities (30, 31). In Nelson's study (32), boys and girls were analysed together to identify five profiles: i) 'social', ii) 'all-around', iii) 'unstructured recreation', iv) 'employed' and v) 'study'. The profiles differed by sex, race/ethnicity, socioeconomic status, school type and location. The 'study' group consistently showed the best perception of school climate, academic achievements, and the lowest levels of truancy and victimisation, while the 'unstructured recreation' group showed the worst outcomes for wellbeing/functioning.

The three remaining studies each examined different aspects of wellbeing/functioning (30, 31, 33). For example, Bartko (30) demonstrated that adolescents who participated in pro-social activities had the best psychosocial functioning. In Metzger's study (31), participation in organised activities was also associated with positive outcomes; however, in certain profiles (e.g. 'school and community') it was associated with negative outcomes (e.g. delinquency, suspension). Zarrett's (33) six identified profiles differed in terms of 'positive youth development', 'contribution' and 'depression', but not in 'risk behaviour', which was consistent across profiles.

Variable-centred time use

Table 3 summarises the 24 studies examining variable-centred time use. A wide range of mainly short measures was used to estimate habitual time spent in specific activities, which generally comprised physical activity, sedentary behaviour (often screen time specifically) and sleep. Similarly, various HRQL measures were used, with only two studies employing utility measures (34, 35).

Relationships between HRQL and variable-centred time use

Of the five studies stratifying by sex (23, 36-39), two found different results for boys and girls where the associations were only observed in boys (36, 38). The participants' ages ranged from 9-19 years

and most studies were conducted in wealthy European countries, Australia, United States, Canada and Japan.

15 studies (11 cross-sectional, four longitudinal) investigated physical activity and HRQL, perhaps reflecting the global obesity epidemic (40). All used stylised questions to estimate frequency and/or duration time in physical activity; most used previously-reported questions (23, 34, 35, 37, 38, 41-47), while the remainder used study-designed measures (22, 36, 37, 48). Many physical activity measures comprised one to three items. Of the 15 studies, 13 showed that more time in moderate-vigorous physical activity was associated with better HRQL. The strongest association was observed in Omorou's (44) longitudinal national study of 1445 French 14-18 year olds, where the mean HRQL of adolescents who met vs did not meet physical activity recommendations over a two-year period was 0.3SD higher on the Duke Health Profile (sample mean 71.0, SD 15.5). The other 12 studies showed similar but weaker associations. Thus, more physical activity, when assessed in isolation, is associated with somewhat better HRQL.

Sedentary behaviour and HRQL has also been widely studied (13 studies; 10 cross-sectional, three longitudinal). Of the 13 studies, 11 examined screen time alone (22, 23, 34, 39, 41, 46, 47, 49-52), one examined reading and music listening on top of screen time (38), and one examined overall sedentary behaviour (duration of sitting) (44). Most studies (12 of 13) showed that more sedentary behaviour was associated with marginally worse HRQL. Mathers'(52) cross-sectional community survey of 925 Australian 13-19 year olds was the most robust in using a validated 24-hour time diary; all others used stylised questionnaires. Children with <2 hours/day of screen time scored 3.35 (95% confidence interval (CI): 1.23; 5.47) units higher on the PedsQL (range 0-100; higher scores indicate better HRQL) and 1.43 (95% CI: 0.07; 2.80) units higher on the KIDSCREEN (range 0-100; higher scores indicate better HRQL) than those with ≥4 hours/day (52). Ten other studies showed comparable results, indicating that more screen time, when assessed in isolation, is associated with marginally worse HRQL. Interestingly, in Jalali-Farahani's study (38), HRQL was not associated with music listening and reading -- suggesting that the type of sedentary behaviour is important.

Sleep and HRQL was investigated in seven studies with stylised questionnaires (five cross-sectional, two longitudinal), mostly in the form of sleep duration (six out of seven). Most showed that longer sleep duration or an absence of sleep deprivation, was associated with slightly better HRQL (22, 34, 53-56). For example, in Chen's (22) longitudinal community survey of 7794 Japanese 9-13 year olds, children with <8 hours/day of sleep were 1.25 times (95% CI: 1.01; 1.54) more likely to have worse HRQL (dichotomised) than those with ≥9 hours/day of sleep. Similarly, Paiva's (56) cross-sectional national study of 3195 Portuguese 12-19 year olds showed that children whose weekday and weekend sleep duration differed by ≥3 hours (i.e. suggesting sleep deprivation on certain days) had 0.81 units (0.2SD) lower HRQL (mean 38.6 SD 5.8, higher scores indicate better HRQL, p=0.003).

DISCUSSION

Principal findings

Due to a dearth of research, we could not determine how time use patterns are associated with utility-based HRQL. However, we found some limited evidence from five studies that overall time use is associated with health profile HRQL and wellbeing/functioning. Thus, a well-balanced lifestyle, i.e. high participation in multiple types of activities (e.g. 'all-rounder', 'productive') was associated with better academic performance and social support and less problematic behaviours, while high involvement in leisure activities alone (e.g. 'unstructured recreation') was associated with the worst academic involvement, problematic behaviour and psychological functioning. Regarding aspects of time examined in isolation from each other (an inherently flawed approach, as outlined in the Introduction), frequent participation in physical activity, less screen time and adequate/more sleep all consistently showed small to moderate associations with somewhat better HRQL.

Interpretation of findings

Person-centred time use studies

Contrary to expectations, the one extant study (28) suggested that a 'well-balanced' adolescent lifestyle was not associated with better HRQL in boys and, although there was some evidence of an association in girls for overall HRQL, this did not play out as differences in the more detailed dimensions underlying the global measure. This could be the truth –- one interpretation being that cumulative effects of health-enhancing and health-compromising activities may not become subjectively apparent until adulthood. Alternatively, these broadly null findings might reflect study limitations, including low response rate (52%), relatively small sample size, homogeneous sample (adolescents in full time education and living at home), blunt time diary (31 activities in 15 minute blocks; not validated for this age group) and/or blunt HRQL measure (the 10-item KIDSCREEN). While well conducted, this study does not suffice to definitively address the question. Nevertheless, it provided more insight than any other studies included.

Interpreting the findings of the four studies that examined overall time use and wellbeing/ functioning is challenging due to the heterogeneity of exposure and outcome measures. All studies utilised stylised time use questionnaires with limited items (6 to 19) and diverse measures of wellbeing/functioning (e.g. Child Behavior Checklist, Profiles of Student Life -- Attitudes and Behaviors Survey). Residual confounding is another possible issue as, for example, none adjusted for body mass index (a strong correlate of HRQL in adolescents) (57). Low response rate leading to selection bias is a potential issue in three studies (30, 32, 33). Due to this variability we have interpreted results cautiously and cannot draw definitive conclusions.

Variable-centred time use

The findings that frequent participation in physical activity, less screen time and adequate/more sleep are consistently associated with somewhat better HRQL was more compelling. Individual associations appeared to be small to moderate in size and therefore of uncertain public policy significance; it is not known whether, when combined, these would 'add up' to larger overall beneficial associations with

HRQL. Limitations include utilisation of study-designed measures (22, 34, 36, 37, 39, 48, 49), stylised questionnaires without specific types of activities (e.g. sports, dance, athletics for physical activity) (22, 23, 34, 36-38, 41-45, 47, 48) and crude time use measures without actual duration spent on the activity (22, 23, 36, 42). These are major issues, because such measures are known to be extremely inaccurate when compared with actigraphy (58). Ceiling effects for HRQL were observed in many studies, restricting the ranges of differences that were possible, and residual confounding was likely (e.g. 12 studies did not adjust for body mass index). However, the major weakness in these studies is that activities were analysed in isolation, neglecting the compositional nature of time use, so that attributing cause and effect to any one activity type is innately flawed.

We identified, but did not discuss, one relevant systematic review that did not meet our selection criteria (though four of its included papers did (22, 23, 41, 46) and were included). Suchert investigated sedentary behaviour and mental health and similar to our findings, found that in 10 of 14 studies more screen time was associated with worse HRQL and/or wellbeing/functioning (59).

Strengths and limitations

Strengths of this review include a comprehensive search strategy of a wide range of databases going back 20 years, and *a priori* inclusion and exclusion criteria. We included papers published in peer-reviewed journals only. Limitations include restriction to English language publications, and we were unable to conduct dual study screening, selection and data extraction. Moreover, almost all studies included were from wealthy developed countries (except for two Iranian studies) (38, 49), limiting our conclusions to these nationalities and socioeconomic statuses. Meta-analysis was not possible due to the high heterogeneity in methodological designs between studies, most of which do not account for the finite, bounded nature of time. Furthermore, a scoping review such as this does not provide formal assessment of methodological quality of the studies included.

Implications and future research

This review critically appraises the evidence regarding relationships between time use and HRQL in largely-healthy adolescents. It strongly suggests that time use patterns may be an important modifiable determinant of HRQL, wellbeing and functioning in this age group. However, quantity and quality was extremely limited, as we could locate only one empirical cross-sectional person-centred study on time use in relation to HRQL. Among the other studies reviewed we identified a lack of standardised, validated time use instruments; methodological variability in time use analyses and selection of covariates; and failure to account for the interconnected nature of activities across the full 24-hour day using appropriate techniques. We concur with Hunt's (26) and Ferrar's (24) call for valid age-appropriate instruments to investigate time use and HRQL and wellbeing in adolescents.

Large-scale representative surveys are now needed that use valid measures incorporating all major types of activities alongside validated, widely-used (and preferably utility based) HRQL measures. This would allow researchers to chart complex interactions between time use and HRQL in adolescence or even across lifespans, and assist clinicians, researchers and policymakers to identify clusters of individuals at risk. This could in turn assist in a more tailored intervention approach in developing adolescent policy that considers the multiple ways in which adolescents spend their time.

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CONFLICT OF INTEREST

The authors declared no potential conflicts of interest, including no specific financial interests relevant to the subject of this manuscript.

ABBREVIATIONS

- CI: Confidence intervals
- HRQL: Health-related quality of life
- PedsQL: Paediatric Quality of Life Inventory
- QALY: Quality-adjusted life years
- SD: Standard deviation

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TABLES

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Published in 1996-2016	Primarily focused on children aged less than 10 years or adults
Primary focus on healthy individuals aged 10-19 years	Clinical or special populations (e.g. children with autism spectrum disorder)
Sample size more than 100	Theoretical or methodological papers or literature reviews
Exposure variable reported as actual time spent on activities	Theses or book chapters
Outcomes measured using validated tools	Time use expressed as metabolic equivalents or energy expenditure
English language	
Published in peer-reviewed journals	

Table 2. Summary of included studies on person-centred time use. All time use measures were subjective; only studies with validated measures of HRQL/wellbeing included.

Author (Ref) year	Sample; design	N (% boys); response; Age (yr)	Measures [i]	Main findings [ii]	Limitations
Hunt (28) 2014	Community based, Ireland. Cross-sectional	667 (47% boys) 52% response 15-19yr	- Time use: 31 time-diary items in 15-minute categories; 1 weekday and 1 weekend day; adapted from Irish Economic and Social Research Institute time use survey for adults 2005 - HRQL: KIDSCREEN-52; 10 domain scores + 10-item KIDSCREEN-10 global HRQL score - Stratification: sex	Time use profiles derived for boys and girls separately using latent profile models • Boys, 3 profiles: 'productive' (more time in study, paid work, housework, and less time in leisure), 'high leisure' (more time on leisure but less time on study, paid work, housework, sleep, self-care and school), and 'all-rounder' (average amount of time in sleep, self-care, school, slightly above-average leisure time, and more time in study and housework). • Girls, 2 profiles: 'moderate study/high leisure' (less time in sleep, moderate in study, more in leisure); 'moderate study/low leisure' (more time in sleep, housework and study, less in leisure). • Boys: no association of time profiles with global HRQL. Girls: 40% in the 'moderate study /higher leisure' group scored >0.5 SD above the mean for global HRQL, vs 18% in the 'higher study/lower leisure' group (p=0.006, association remained after adjustment for multiple testing). • Time profiles vs HRQL subscales: none significant after adjustment for multiple testing.	- A non-utility measure for HRQL - All adolescents were in school and living at home, which may have reduced variability
Bartko (30) 2002	Community based, US. Cross-sectional	918 (50% boys) - 16-17yr	- Time use: 11 stylised items; study designed - Wellbeing/functioning: GPA, problem behaviour (15-item), Children's Depression Inventory, Harter's Global Self-Worth scale, Child Behavior Checklist - Confounder: sex, SES	• Out of 7 wellbeing scales analysed, time use profiles were associated with 6 wellbeing scales. • Externalising behaviour differed the most between time profiles: the 'uninvolved' group had the highest (i.e. worst) score (mean 8.51 SD 9.27) while the 'high involved' group had the lowest score (mean 4.91 SD 5.35).	- Limited list of activities - Study designed time use instrument that has not been validated. - Crude measures of time use
Metzger (31) 2009	Community based, US. Cross-sectional	2495 (49% boys) 99% response 13yr	- Time use: 6 stylised items; Adapted from the Search Institute's Profiles of Student Life: Attitudes and Behaviors Surveys - Wellbeing/functioning: GPA, school attendance, suspension histories, Children Institute's Assessment of Adolescent Behaviors and Attitudes Towards School and Community, - Confounder: sex, age, ethnicity	• Time profiles were associated with all nine aspects of wellbeing measured. • The most significant association was in the 'negative affect' score where the 'uninvolved' group reported the worst while the 'multiply involved' showed the best score (i.e. least negative affect) (marginal mean 2.20 and 1.89 respectively). • Effect size could not be assessed as the standard deviation was not provided.	- Limited list of activities

Author (Ref) year	Sample; design	N (% boys); response; Age (yr)	Measures [i]	Main findings [ii]	Limitations
Nelson (32) 2009	National sample, US. Cross-sectional	6338 (51% boys) 41% response 10th grade	- Time use: 18 stylised items; based on the Educational Longitudinal Study of 2002 - Wellbeing/functioning: Educational Longitudinal study of 2002; 6-item survey on recognitions at school - Confounder: sex, age, ethnicity, school	• Time profiles were associated with all aspects of wellbeing measured. • Truancy and delinquency differed the most between time profiles: the 'unstructured recreation' profile (less time in academic and enrichment activities outside of school and social activities but more screen time) reported the highest levels of truancy (mean 1.73 SD 0.56) while the 'study' group (more time in homework, reading, school clubs and sports but less time on social activities) had the lowest truancy score (mean 1.49 SD 0.39).	- Different scales were used for each aspect of wellbeing making the results challenging to interpret.
Zarrett (29) 2009	National sample, US. Cross-sectional	1357 (48% boys) 39% 11yr	- Time use: 19 stylised items; study designed - Wellbeing/functioning: PYD, Profiles of Student Life–Attitudes and Behaviors Survey, Teen Assessment Project Survey Question Bank, CES-D, Monitoring the Future questionnaire - Confounder: sex, ethnicity, SES, youth goal orientation	• In examining the association between six time use profiles and four wellbeing scales, the 'high engaged' profile was associated with the best PYD while the 'nonsports' profile showed the worst PYD score (mean (SE) 74.84 (1.32) and 68.00 (0.57) respectively, $p<0.05$). Similar results were found in the 'contribution' score. • The 'high engaged' and 'nonsports' groups had the worst 'depression' score while the 'sports only' group had the best score (mean (SE) 14.60 (1.06), 14.07 (0.45) and 11.78 (0.69) respectively, $p<0.05$). • Risk behaviour did not differ between the six time use profiles.	- Study designed time use instrument that has not been validated.

[i] CES-D: Center for Epidemiological Studies Depression Scale, GPA: Grade point average, PYD: Positive youth development, SES: Socioeconomic status
[ii] SD: Standard deviation, SE: Standard error

Table 3. Summary of included studies on variable-centred time use. All time use measures were subjective.

Author (Ref) year	Sample; design	N (%boys); response; Age (yr)	Measures [i]	Main findings	Limitations
Boyle (35) 2010	Community based, England. Cross-sectional	1771 (50% boys) 33% response 11-15yr	- PA: 24 stylised items; Western Australian CAPANS - HRQL: PedsQL, EQ-5D - Confounder: sex, age, ethnicity, SES - Stratification: season	• There was no difference in HRQL between adolescents meeting vs not meeting recommended PA guidelines.	
Sánchez-López (42) 2008	Community based, Spain. Cross-sectional	1073 (48% boys) 76% response 11-13yr	- PA: 2 stylised items; activity type unspecified; actual duration unspecified; CHIP-CE - HRQL: CHIP-CE - Confounder: sex, age, BMI	• Physically active adolescents had higher HRQL scores except in risk avoidance domain. Satisfaction, comfort, resilience and achievement domain scores were higher by 0.26, 0.12, 0.51, 0.29 scores respectively (P<0.001) on a scale of 1-5. Risk avoidance was higher in those that are sedentary by 0.18 (P<0.001). Effect size of CHIP-CE: 0.20=small, 0.50=moderate, 0.80=large.	- PA measured using two items of CHIP-CE. - Crude measures of time use
Spengler (43) 2013	National sample, Germany. Cross-sectional	1828 (51% boys) 40% response 11-17yr	- PA: 3 stylised items; activity type unspecified; MoMo-PAQ - HRQL: KINDL-R - Confounder: SES	• An hour increase in PA per week raised total HRQL score by 0.42 points (P<0.001, SD 10.3) on a 0-100 scale. • Physical activity explained 2.4% of variance of HRQL by a linear regression (P<0.001).	
Liu (36) 2015	Community based, Japan. Longitudinal	5238 (48% boys) 50% response 5-7; 11-13yr	- PA: 1 stylised item; activity type unspecified; actual duration unspecified; study designed - HRQL: COOP - Confounder: breakfast eating, sleep duration, headache, abdominal pain - Stratification: sex	• Adolescents with frequent PA at follow-up were more likely to report better HRQL (86.4% vs 79.7% good self-reported health in boys, p<0.001; 82.5% vs 78.7% in girls, p=0.015). There was no significant difference at baseline (aged 5-7 years). • Boys who reported persistent (i.e. at baseline and follow-up) in participation in PA were more likely to have better HRQL at age 12 years (OR (95% CI) 1.47 (1.14; 1.89)). No difference was found in girls.	- Study designed time use instrument that has not been validated. - Crude measures of time use - Follow-up bias
Petracci (48) 2013	Community based, Italy. Cross-sectional	4338 (50% boys) 95% response 13-14yr	- PA: 1 stylised item; activity type unspecified; study designed[ii,iii,iv,v] - HRQL: EQ-VAS - Confounder: no	• Adolescents with <2 hours/week of PA had lower HRQL with small effect size. • There was no significant difference between adolescents who exercised 2-11 hours/week and those who exercised >11 hours/week.	- Study designed time use instrument that has not been validated.
Galan (37) 2013	National sample, Spain. Cross-sectional	21811 (-) 78% response 11-18yr	- PA: 1 stylised item; activity type unspecified; study designed - HRQL: KIDSCREEN - Confounder: age, BMI, ethnicity, SES, numerous others - Stratification: sex	• Increasing PA was associated with higher HRQL especially when increasing from 5 to 7 days/week of moderate-vigorous PA (unstandardised ß (95% CI) 3.0 (1.7; 4.3), and 5.1 (3.7; 6.4) respectively; mean 50 SD 10).	- Number of each sex was not stated. - Study designed time use instrument that has not been validated.

Author (Ref) year	Sample; design	N (%boys); response; Age (yr)	Measures [i]	Main findings	Limitations
Breslin (45) 2012	Community based, Northern Ireland. Cross-sectional	1424 (45% boys) 73% response 9-11yr	- PA: 2 stylised items; activity type unspecified; adapted from PASS project[ii, iv] - HRQL: CHIP-CE, KIDSCREEN - Confounder: sex, BMI	• Adolescents with high PA had significantly higher HRQL (P=0.003) with small effect size ($\eta_p^2 \approx 0.01$).	
Dalton (41) 2010	Community based, US. Cross-sectional	152 (46% boys) 29% response 11-12yr	- PA: 2 stylised items; activity type unspecified; adapted from Glasgow's Measures of Patient Health Behaviors 2005 - ScrT: subjective; 2 items; adapted from Glasgow's Measures of Patient Health Behaviors 2005 [ii] - HRQL: PedsQL - Confounder: SES, BMI	• Being physically active was associated with a higher level of total HRQL score on a scale of 0-100 (standardised β=0.24 p<0.004). • A longer duration of screen time was associated with a lower total HRQL score (standardised β=-0.45 p<0.001).	- Small sample size
Gopinath (46) 2012	Community based, Australia. Longitudinal	169 (44% boys) 75%; 52% response 12; 18yr	- PA: 10 stylised items; Adolescent Physical Activity Recall Questionnaire - ScrT: 5 items; Adolescent Sedentary Activity Questionnaire - HRQL: PedsQL - Confounder: sex, age, ethnicity, SES, BMI	• Adolescents with the highest level of PA (≥2.57 vs ≤1.21 hours/day) had higher overall HRQL on a scale of 0-100 (mean (SE) 82.3 (0.9) and 79.15 (0.9) respectively). • Those who frequently participated in PA over 5 years (≥2.57 vs ≤1.21 hours/day) had a higher HRQL (mean (SE) 83.2 (1.6) and 79.57 (1.4) respectively). • Adolescents with high screen time (≥3.93 vs ≤2.50 hours/day) had lower physical, psychosocial, emotional, school and overall HRQL (mean (SE) 78.30 (0.9) and 81.83 (0.9) respectively) • Those with high screen time (≥3.93 vs ≤2.50 hours/day) over 5 years had lower HRQL (mean (SE) 75.87 (1.5) and 82.21 (1.5) respectively, p<0.001).	- Follow-up bias
Lacy (24) 2012	Community based, Australia. Cross-sectional	3040 (56% boys) 51% response 11-18yr	- PA: 5 stylised items; activity type unspecified; actual duration unspecified; adapted from the 2002 National Children's Nutrition Survey - ScrT: 8 stylised items; adapted from the 2002 National Children's Nutrition Survey - HRQL: PedsQL - Confounder: SES, BMI - Stratification: sex, age	• Boys who were most physically active at recess, lunchtime and after school every day had higher HRQL by 5.31 (95% CI 3.56; 7.07, p<0.001), 8.11 (95% CI 6.16; 10.1, p<0.001) and 6.37 (95% CI 3.24; 9.50, p<0.001) units on a 0-100 scale. Similar results were found in girls. • An hour increase in screen time was related to 1.30-unit reduction in HRQL in boys (95% CI -1.70; -0.89, p<0.001) and 1.82-unit reduction in HRQL in girls (95% CI -2.42; -1.23, p<0.001).	- Crude measures of time spent on PA recorded.
Omorou (44) 2015	National sample, France.	1445 (43% boys)	- PA: 25 stylised items; activity type unspecified; IPAQ - SB: 2 stylised items; IPAQ	• The cumulative level of meeting PA guidelines was associated with an increase in overall HRQL (standardised β= 5.5-unit ± 1.0, p<0.001), social (8.7 ±1.2 p<0.001), physical (3.8 ± 1.2, p=0.001), and mental (5.2 ± 1.4, p<0.001) scores	- Response rate not provided - Follow-up bias

Author (Ref) year	Sample; design	N (%boys); response; Age (yr)	Measures [i]	Main findings	Limitations
	Longitudinal	- 14-18yr	- HRQL: Duke Health Profile - Confounder: sex, age, SES, BMI	on a scale of 0-100 than not meeting PA guidelines. • Cumulative high SB (>7 hours/day) was correlated with lower HRQL (standardised β=-3.1 ± 1.2, p=0.003).	
Finne (47) 2013	National sample, Germany. Cross-sectional	6813 (51% boys) 67% response 11-17yr	- PA: 1 stylised item; activity type unspecified; adapted from KiGGS survey - ScrT: 1 stylised item; adapted from KiGGS survey - HRQL: KINDL-R - Confounder: age, SES, ethnicity, BMI, smoking, alcohol, sleep duration	• High PA was associated with higher levels of HRQL. There were small to moderate effect sizes for daily vs. no regular PA for both sexes. Emotional and social wellbeing were affected the most in boys (moderate effects: d=0.56-0.59) and physical then social wellbeing in girls (small to moderate effects: d=0.43 and d=0.32). • High screen time was related to lower HRQL. The largest effect was found in school domain (d=-0.37). In boys, only physical wellbeing and school were significantly affected by high screen time (p<0.001), with the largest effects for school (d=-0.31)	- Crude measures of time use
Chen (23) 2005	Community based, Japan. Longitudinal	7794 (50% boys) 90%; 75% response 9-13yr	- PA: 1 stylised item; activity type unspecified; actual duration unspecified; study designed - ScrT: 2 stylised items; study designed - Sleep: 2 stylised items; study designed [ii] - HRQL: COOP - Confounder: sex, age, BMI	• Adolescents who participated in PA 'seldom' or almost never' were more likely to have poorer HRQL than those with 'very often' at baseline (OR (95% CI) 1.58 (1.38; 1.81) and 1.92 (1.29; 2.87) respectively). Those who reduced PA and kept low PA were associated with poorer HRQL (OR 2.10 (1.84; 2.39) and 2.21 (1.03; 4.09) respectively). • Adolescents who increased screen time (<2 vs ≥2 hours/day) were associated with poor HRQL (OR 1.24 (1.10; 1.39)). Those with ≥ 3h television viewing were associated with poorer HRQL (OR 1.20 (1.10; 1.39)). • Those with less sleep (<8 vs ≥9 hours/day) were associated with poorer HRQL (OR 1.25 (1.01; 1.54)).	- Study designed time use instrument that has not been validated. - Crude measures of time use for PA - Follow up bias
Chen (34) 2014	Community based, Australia. Cross-sectional	3353 (49% boys) - 9-15yr	- PA: 1 stylised item; activity type unspecified; adapted from the Youth Risk Behavior Survey - ScrT: 2 stylised items; adapted from the Youth Risk Behavior Survey - Sleep: 5 stylised items; study designed[iv,v] - HRQL: CHU9D - Confounder: sex, age, SES	• An increase in the number of physically active days was correlated with an increase in HRQL by 0.004-unit (SE=0.001, P<0.001 and SE=0.002, P = 0.05 for primary and high school children respectively) on a scale of 0-1. • Each additional hour of screen time was associated with a decreased adjusted mean utility of -0.008 and -0.009 (SE=0.001, P <0.001 both) for primary and high school students respectively. • An extra hour of sleep was significantly associated with an additional adjusted mean utility of 0.010 (SE=0.003, P<0.001) and 0.014 (SE=0.014, P= 0.001) for primary and high school students respectively.	- Response rate was unknown. - Inclusion criteria: disadvantaged communities. - Study designed time use instrument for sleep that has not been validated.
Jalali-Farahani (38) 2016	Community based, Iran. Cross-sectional	465 (51% boys) 96% response 14-17yr	- PA: 3 stylised items; activity type unspecified; QAPACE - ScrT: 2 stylised items; QAPACE - Music/reading: 2 stylised items; QAPACE	• PA was positively related to HRQL during school period. • Screen time was negatively associated with school functioning during school period. • There was no association between sleep and HRQL. • Time spent on music listening/reading was positively correlated to HRQL during	

Author (Ref) year	Sample; design	N (%boys); response; Age (yr)	Measures [i]	Main findings	Limitations
			- Sleep: 1 stylised item; QAPACE [iv,v] - HRQL: PedsQL - Stratification: sex, school/vacation	school period. During vacation period, they were negatively associated with emotional functioning in boys.	
Kantor (51) 2015	Community based, US. Cross-sectional	448 (51% boys) 96% response 7-12yr	- ScrT: 2 stylised items; SPAN[vi] - HRQL: PedsQL - Confounder: sex, ethnicity, grade	• Greater duration on television was associated with lower HRQL (unstandardised ß=-0.97-unit, SE 0.41, p<0.05) on a 0-100 scale.	- Inclusion criteria: Hispanic children who could read in English or Spanish.
Dolatabadi (49) 2013	Community based, Iran. Cross-sectional	444 (52% boys) 90% response 12-15yr	- Computer games: 1 stylised item; study designed - HRQL: WHOQOL-BREF - Confounder: SES	• There was a positive relationship between duration of computer games playing and HRQL (p=0.01, r=0.11), but no relationship between playing computer games (regardless of duration) and HRQL.	- Study designed time use instrument that has not been validated.
Herman (39) 2015	National sample, Canada. Cross-sectional	7725 (51% boys) 68% response 12-17yr	- ScrT: 3 stylised items; study designed[vi] - HRQL: SRH, SRMH - Confounder: age, BMI, ethnicity, SES, lifestyle - Stratification: sex	• Adolescents with high screen time were more likely to have worse HRQL (boys: OR (95% CI) 1.28 (1.08, 1.52); girls: 2.06 (1.74, 2.44)), and worse mental health (boys: 1.34 (1.11, 1.62); girls: 1.52 (1.28, 1.80)).	- SMRH not previously validated in adolescents. - Study designed time use instrument that has not been validated.
Mathers (52) 2009	Community based, Australia. Cross-sectional	925 (50% boys) 56% response 13-19yr	- ScrT: 259 time-diary items; MARCA - HRQL: CHQ, KIDSCREEN, PedsQL, K-10, SDQ - Confounder: SES, sex, age, BMI	• Adolescents with the highest screen time (≥255 vs <121 minutes/day) had poorer KIDSCREEN scores (unstandardised ß (95% CI) -1.43 (-2.80; -0.07), P=0.04) and PedsQL scores by 3.35 on a scale of 0-100 (95% CI -5.47; -1.23, P=0.002).	
Goldfield (50) 2015	Community based, Canada. Cross-sectional	358 (27% boys) - 14-18yr	- ScrT: 3 stylised items; study designed - HRQL: PedsQL - Confounder: age, sex, SES, ethnicity, BMI, PA intensity, PA duration, caloric intake	• Screen time duration was associated with lower HRQL (adjusted r=-0.16, standardised ß=-0.16, p=0.009). • Computer time and video games were associated with lower HRQL.	- Inclusion criteria: overweight and obese adolescents - Study designed time use instrument that has not been validated.
Segura-Jimenez (55) 2014	Community based, Spain. Cross-sectional	684 (53% boys) 95% response 6-18yr	- Sleep: 1 stylised item; HBSC - HRQL: HBSC - Confounder: age, sex, SES	• Sleep durations of >10 hours/day in children <12 years old and >9 hours/day in adolescents were associated with reporting no health complaints (OR 2.3, P=0.005 and OR 1.7, P=0.047 respectively).	
Paiva (56) 2015	National sample,	3195 (46% boys)	- Sleep: 3 stylised items; HBSC - HRQL: KIDSCREEN	• Adolescents with sleep deprivation had lower HRQL but the effect size was small (eta^2=0.003; p=0.003).	- Limited information about actual sleep

Author (Ref) year	Sample; design	N (%boys); response; Age (yr)	Measures [i]	Main findings	Limitations
	Portugal. Cross-sectional	90% response 12-19yr	- Confounder: no		duration
Tzischinsky (53) 2011	Community based, Israel. Cross-sectional	470 (50% boys) - 12-16yr	- Sleep: 2 stylised items; SSHS - HRQL: PedsQL - Confounder: no	• Weekday sleep duration was significantly correlated with HRQL (r=0.17, p<0.001 and r=-0.32, p<0.001 respectively).	
Gustafsson (54) 2016	Community based, Finland. Longitudinal	568 (47% boys) 63-67% response 10-15yr	- Sleep: 4 stylised items; HBSC - HRQL: PedsQL - Stratification: age	• The association between sleep and HRQL was strongest in the 15-year olds, weaker in the 12-year olds and no association in the 10-year-olds.	- Follow-up bias

[i] BMI: Body mass index, CAPANS: Child and Adolescent Physical Activity and Nutrition Survey, CHIP-CE: Child Health and Illness Profile, CHQ: Child Health Questionnaire, CHU9D – Child Health Utility 9D, COOP: Cooperative Functional Assessment Charts, EQ-5D: EuroQoL five dimensions questionnaire, EQ-VAS: EuroQoL Visual Analogue Scale, HBSC: Health Behaviour in School-aged Children, IPAQ: International Physical Activity Questionnaire, K-10: Kessler Psychological Distress Scale, KiGGS: German Health Interview and Examination Survey, MoMo-PAQ: MoMo physical activity questionnaire, PA: Physical Activity, PASS: Physical Activity in Scottish Schoolchildren, PedsQL: Pediatric Quality of Life Inventory, QAPACE: Quantification de l'Activite Physique en Altitude Chez les Enfants, SB: Sedentary Behaviour, ScrT: Screen Time, SDQ: Strengths and Difficulties Questionnaire, SES: Socioeconomic status, SPAN: School Physical Activity and Nutrition, SRH: Self-Rated Health, SRMH: Self-Rated Mental Health, SSHS: School Sleep Habits Survey, WHOQOL-BREF: WHO Quality of Life-BREF
[ii] Dietary pattern [iii] Weight status [iv] SES: Socioeconomic Status [v] Sex [vi] Physical activity (not time-related)

FIGURES

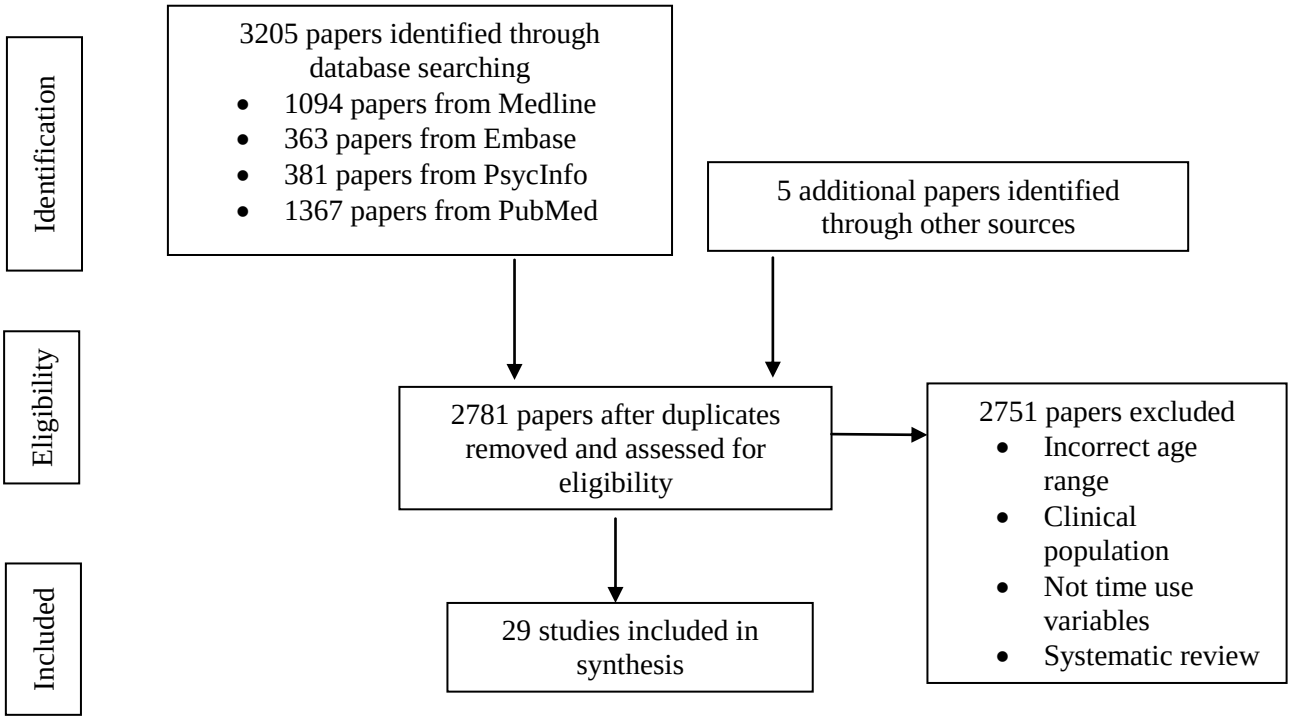

Figure 1. Progress through the stages of study selection