Osteoarthritis and Activity at Roonka Flat:

Finding Gender at a Hunter-gatherer Burial Site.

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A thesis submitted in the partial fulfilment of the requirements for the degree of Master of Arts in Anthropology, the University of Auckland, 2022.

"Up to a point, a digging stick looks rather like a spear. But the differences between them, though apparently small, are crucial ..."

Catherine H. Berndt, 1978: 76

Abstract

Examining gender in Aboriginal Australia has often relied upon personal historical accounts and ethnographic observations of gender roles and rituals. Many of these are from a European and non-Aboriginal perspective from a post-contact Australia. Our current understandings of precolonial Aboriginal gender roles heavily rely on these early European perspectives. Gender, as a socially constructed binary, has a significant impact on the daily life of everybody within a society. This includes influencing what people eat, access to knowledge, and what tasks and activities are allotted to a person. The skeletal embodiment of these differences in activity has long been observed upon the skeleton, and osteoarthritis (OA) has been one of the more recurrent approaches to activity.

OA is a commonly found pathology amongst skeletal collections. With the absence of large precolonial skeletal collections found in Australia, in order to examine the presence of gender-associated skeletal pathology, OA is appropriate to gain an initial understanding.

In this thesis, a pathological examination of OA at the site of Roonka Flat (8,000 BP – 200 BP) is undertaken to understand if embodied indicators of activity can be used to understand precolonial divisions of gender. While early historical accounts and early ethnographies have suggested gender-specific roles, more recent work has suggested that Aboriginal gender roles were more flexible. First, the non-vertebral skeleton of each individual (n=90) was examined across age and sex categories to understand the overall distribution of OA and where differences between the sexes lay. Next, the vertebral column, divided by centra and facets, was examined for differences in Vertebral Osteophytosis (VO) and OA. This was examined in relation to non-vertebral OA to understand if gendered differences in joint degeneration could be understood, and if any individuals are unique in their degeneration in comparison to others of their age or sex. While patterns of OA cannot be definitively connected to differences in gender,

evidence suggests that gender did not play as much of a role in labour as has been believed. Instead, while existing in a gendered society, labour itself was flexible and could be carried out with some variability.

Acknowledgements

First, I thank Judith Littleton for the opportunity to contribute to work being conducted at the Roonka Flat burial site, and I also thank Bruce Floyd. The feedback and knowledge gained from you both has been truly appreciated.

I am grateful for the support provided by the Marsden Grant, awarded by the Royal Society of New Zealand.

To my friends, family, Spike and Milligan. Thank you endlessly.

Finally, I acknowledge the First People of the River Murray and Mallee who approved this project, and whose continued trust guides our research. Thank you.

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Introduction

1.1 Background to thesis

When attempting to examine gender in past societies using skeletal remains, what is often relied upon is the sex of an individual. This disparity can cause issue when attempting to examine gender more specifically. Sex can be defined as the biological and physical differences between people based on the function of their reproductive system. This includes the formations that distinguish this indicated by chromosomes, gonads, external genitalia, and internal reproductive organs (Zuckerman and Crandall, 2019; Fausto-Sterling et al, 2012a; Ainsworth, 2015). The most widely known sexes are male, female, and intersex and while people are born a sex, people are not born a gender.

Gender is the social and cultural understanding of sex, and the enacting of behaviours, roles, and appearances that may indicate this (often tied to physiological characteristics associated with a given sex) (Zuckerman & Crandall, 2019). While all cultures may have overarching gender identities which are similar to the western genders of man and woman, what encompasses these genders may vary cross-culturally, even within geographic regions. Gender does not remain fixed and is subject to change based upon age, social status, religion, and ethnicity (De Leiuen, 2013). Often it can be recognised through clothing, adornments, and make-up – things that often do not survive the burial record. When European settlers first wrote their accounts about Aboriginal culture and gender dynamics, they did so from a European understanding of gender.

While the study of gender through human remains is occurring elsewhere, it has been slow to develop in Australia. Around the world, the archaeology of gender has often been the examination of patterns, and understanding where such patterns vary and how (Agarwal, 2012; Geller, 2009a). In Australian Aboriginal history, the earliest written records of gender come fromEuropean accounts written from the late 18th century. From this point on, broadly held perceptions about Aboriginal gender were observed through a western lens. This has limited our knowledge on gender and social organisation across different Aboriginal societies, but also how this organisation may have varied across the continent. Increasingly, anthropological methods are being utilised to increase our knowledge of Aboriginal gender including ethnography, archaeology, and bioarchaeological analysis. In finding variation and who carried out gendered activities, gender itself can be made visible (Agarwal, 2012; Holliman, 2011). There is little understanding of the precolonial Aboriginal gender binary, so while man and woman are used here, they represent only the people who would have identified with such terms.

This study will focus on potential markers of activity based on the presence of skeletal markers of osteoarthritis (OA), and if these markers can be indicative of gender. This follows theories regarding the embodiment of gender, and how this embodiment may come about. The skeleton is a dynamic organism that changes based on the pressures and actions put upon it, and these actions and pressures are socially and culturally influenced (Grosz, 1995; Joyce, 2005; Perry & Joyce, 2001). In a bioarchaeological context, studies of gender especially adhere to the embodiment of different life experience upon the skeleton. Gender is performed and practiced across one's lifetime, and the subsequent mechanical stresses associated with these practices can be sought (Sofaer, 2006).

Musculoskeletal stress indicators, pathological bone markers, skeletal trauma, exposure to violence, and differential risk diseases have all been used in the seeking of gender in the skeletal record (Larsen, 1998; Lorkiewicz, 2011; Laffranchi et al, 2020; Mazel, 1992; Bird and Rieker, 2008; Tung & Haq, 2012). Although there are difficulties that arise due to dichotomies between sex and gender, gender is something being actively sought out and recognised due to its place as a social organiser. This study will use osteoarthritis and vertebral osteophytosis as indicators of embodied gender, as not only are these some of the most common forms of pathologies observable upon the skeleton, but are often ubiquitous across the sexes. While at an individual level distinguishing the direct cause of OA can be problematic, at a population level these patterns can be reflective of socially influenced joint degeneration.

This study will focus upon the site of Roonka, located in South Australia. This site has been of interest due to its long span of use, and the number of individuals found buried at the site (Pate, 2017; Prokopec, 1979). Roonka has been viewed as a good site in which to examine broad changes to Aboriginal society over time due to variable burial methods, changes observed in burial accompaniments and the potential sample size the site provides. Roonka has had a wide breadth of research conducted which highlights different areas of pathology and differences between the sexes (Pate, 2000; Hill et al, 2019, 2020; Littleton, 2017a; Trow, 2017). By examining this research and examining OA at Roonka, insights into divisions of labour and gender at the site will be further understood and new questions asked.

1.2 Thesis aims

This research aims to achieve two things: (1) examine skeletal differences indicative of activity in order to understand differences across sex categories, and (2) understand if the differences observed across sex categories could be indicative of gender roles or identities. Osteoarthritis as a means of activity is used due to a recognisable cultural contribution when observed within a population. While care must be taken with osteoarthritis due to the number of contributing causes (Age, sex, activity, injury etc.), careful consideration can lessen the impact of overinflating the role of an individual cause. The wider patterns observed in osteoarthritis will provide evidence of how different groups are manifesting joint degeneration, and the implications this may have for labour distributions and the embodiment of gender.

1.3 Ethics

The First Peoples of the River Murray and Mallee, the descendant communities made up of the Ngaiwang, the Ngaiwait, Nganguruku, Ngingtait, Erawirung, Ngaralte and Ngarkat groups, have been in consultation with supervisor Judith Littleton, and provided consent for the continuing of this research. As part of the Roonka Project funded by the Marsden Grant, the ethics of this research have been approved by the University of Auckland Human Participants Ethics Committee.

To respect the descendant community, every effort to maintain care, respect, and to do no harm has been made. All analysis is digital and non-destructive, and has been carried out in order obtain the most representative and accurate information regarding Indigenous history. It is my hope that this information will be of use and of interest to those whose history it reflects.

1.4 Thesis organisation

Chapter two will examine gender in the study of Australian Aboriginal history, focused on how gender has been examined in existing literature, and where this literature could be expanded. This discussion will focus on how the study of Australian Aboriginal history has been limited by past interpretations, and how these interpretations continue to play a role in the understanding of precolonial Aboriginal gender. Chapter three will examine the site of Roonka and why this site was chosen as the focus of this study. Also included is an expansion of the discussion in chapter two, more specifically applied to the Roonka site. Chapter four will cover osteoarthritis as a method applied to activity, and why it was chosen. Materials and Methods is discussed in chapter five. The results of the osteoarthritis analysis will follow (chapter six), succeeded by the discussion of those results in chapter seven.

Chapter two: Understanding Aboriginal Gender

This chapter will examine how gender has been addressed in Aboriginal Australian history and what this means for examining gender from skeletal remains. How gender has been approached previously dictates what information is currently known, and what new research can contribute. This chapter will discuss what is known about Aboriginal Australian gender roles and how we have learned this information, before discussing the ambiguity of such evidence and the challenge this poses.

2.1 What do we know about gender in Aboriginal Australian Societies?

The examination of gender as a focus of study in Australian archaeology was truly acknowledged in the 1990s (Balme & Beck, 1995). Yet, it is even more recently that such study has been applied to Aboriginal Australia. Our earliest sources of information about Aboriginal gender roles mainly stem from the personal accounts of European men as they travelled around Australia from the late 18th to mid-19th centuries. These accounts, distinguishable from the works of ethnographers as personal, untrained accounts, are the earliest written record of gender roles in Australia. Today they continue to affect our understanding of Aboriginal labour organisation through pervasive stereotypes (Kaberry, 1939; Pate, 2006; Reimer, Listemann & Iwan, 1988).

It is because of work by female anthropologists such as (but not limited to) Bell (1981, 1983), Catherine Berndt (1950, 1965, 1978) and Kaberry (1938, 1939) that Australian archaeology began to focus on gender. This is both in the role of women in Aboriginal societies across Australia, and the interrelationship of genders and how this affects social organisation. Stereotypes surrounding the position of Aboriginal women were finally being questioned, allowing for new ideas and information on hunter-gatherer labour divisions and gender dynamics.

2.1.1 Ethnography

2.1.1.1 Modern Perspectives on Ethnography in an Australian Context.

Perspectives on the economic role of Aboriginal women have been driven by broader cultural changes in academia regarding how gender should be approached and studied. Throughout the 1960s-80s, more people began to study gender, and the role gender has as a social organiser. This enabled the complexity of women's roles and hunter-gatherer gender roles to be examined further (De Leiuen, 2013). Modern ethnography was written about and in conjunction with Aboriginal women, and by being able to enter a space not previously examined, women's tasks were made more visible. They could offer a contrast to earlier historical accounts.

Modern accounts appear to widely recognise that women's work focused on gathering edible plants, hunting small animals, and in cases of areas near water, fishing and the collection of shellfish (Meehan, 1975; Kaberry, 1939; Bell, 1983). Early accounts believed the different roles of men and women were due to the social hierarchy of men and the subjugation of women (Eyre, 1845: Krefft, 1865). However, gendered roles fulfil different needs of a community at any given time. These contemporary accounts began to focus on how gathering was a task in which women governed their movement and actions, separate from men. Kaberry (1939) and Bowdler and Balme (2010) both highlight the social aspect of women's roles, with women travelling together in groups and sources of food split between them. Women's work was closely tied to family units, and therefore it was social by nature, both across family and the community.

Age, alongside gender, has been noted as an organiser and divider of labour. As individuals enter or leave culturally understood age categories, the perception of them as a person will change. This includes how labour and gender would change. Observations from personal accounts (Eyre, 1845) and anthropological studies (Meehan, 1975; Balme and Beck, 1995) have shown that children and adolescents varied in what activities they carried out in comparison to their older counterparts. Young children would spend most of their time with or around their mother, learning and watching skills as they grew (Meehan, 1975). As children got older, gendered activities became more imposed until adulthood. Even then, people's social and economic roles would vary across different age ranges. In adulthood, it appears that even though there were broad understandings of who would carry out a particular activity, this was not strict. People were skilled and able at many activities, and these would be carried out as necessary, even if it fell out of their usual routine activity (Littleton, 2017a). Even today, most children are raised with the same cultural approach regardless of gender until approximately mid-to-late teens (depending on the community) (Aboriginal Health Council of South Australia [AHCSA], 2019). At this point, cultural context (and personal choice) will indicate where a person will stand within their community.

However, this variation in activity as people aged carried on throughout adulthood, with frequent flexibility in gendered economic roles being observed across Australia (Kaberry, 1939; Bell, 1981; Balme & Bowdler, 2006). While women are generally described as gatherers, this does not mean that only women gathered. It is also not implied that men only made tools or hunted game. Many accounts discuss the hunting of small game by women that occurred alongside gathering, including lizards, mice, snakes and birds. While this does not invoke the same image as 'Man the Hunter', small prey hunting is more important than big game hunting due to its reliability through periods of stress and seasonal declines (Zihlman, 1989; Linton, 1971; Hill et al, 2019). Gathering is a low-risk, high-reward mode of subsistence and contrasts the high-risk and possible low-reward of hunting. However, this flexibility of hunting and gathering remained within gendered units, as men and women would remain separate throughout the day (Bell, 1981). Time and space were gendered, yet not necessarily the actions being carried out.

While precolonial perceptions of gender have been largely lost due to colonisation, since the 1970s-80s, there have been increasing numbers of Aboriginal individuals discussing and writing about Aboriginal sexuality and gender. Today, the two most common terms for queer-gendered Aboriginal individuals are 'Sistergirl' and 'Brotherboy'. These terms originate from the Tiwi Islands and have been adopted as blanket terms across Australia for Aboriginal and Torres Strait Islanders who do not identify within the gender binary (Baylis, 2015). There is no direct evidence of precolonial non-binary or transgender existence in Australia, which is likely a result of the

European mindset regarding gender imposed upon Aboriginal individuals.

Today there is increasing awareness of how culture and gender interplay and intersect. The Aboriginal Gender Study (2019) conducted by the AHCSA is a recent acknowledgement of this. Many individuals place equal emphasis on the role of men and women as carriers of culture and knowledge. However, the roles played out differ. Women in the discussion emphasised language use and revival as their cultural domain, whereas men found more connection in interacting with the land and other men in their community. The idea that different roles do not mean superiority or inferiority is a sentiment that has often been difficult to grasp in the study of gender – especially as the sentiment has derived from outdated western ideas of gender roles and organisation.

2.1.1.2 Past understandings of Hunter-gatherers

Hunter-Gatherer societies all suffer from stereotypes regarding the divisions and place of gender and activity. 'Man the Hunter' remains a prevalent idea of hunter-gatherer social organisation, with the value of women's roles underestimated and domestic activities regarded as the central aspect of female hunter-gatherer labour (Quinn,1977; Evans-Pritchard, 1965). These stereotypes contributed to the oversimplification of women's roles compared to men's and continue to be perpetuated through imagery of male political figure-heading and reliance on hunting (Malinowski, 1913). Early (western) descriptions of Aboriginal communities emphasised men as the economic, social, and hierarchical heads of the household and community (Eyre, 1845). A consequence of this was that male activities were deemed more important or more socially influential (Bowdler & Balme, 2010; Sangster, 2012).

While the first interactions between colonists and Aboriginal groups varied across the continent, as this thesis focuses mainly on the Murray River valley, the early colonial period can be thought of as the 1830s-1860s. Written predominantly from the perspective of male European colonists, these accounts, while important, have severe limitations in their use as sources of information. Early accounts do not approach Aboriginal Australia as a complex mix of cultures and practices. Instead, Aboriginal cultures are treated as homogenous, and the writers, either purposefully or inadvertently, create an image of an 'other' to shock European audiences and perpetuate European superiority (Jenkin, 1979). This was only driven by the want of land felt by many early colonists, driving forced displacement and forced integration of Aboriginal individuals onto European religious practices and ways of life (Russell & McNiven, 1998; Welch, 1988). Consequently, alongside the massive loss of life and culture, a non-Aboriginal perspective of Aboriginal cultures remains dominant, even to this day.

These early writings lack discussion about the roles and positions of women. However, this is a partial consequence of gendered time and space. Men and women spent the day apart and worked in areas deemed women's-space and men's-space (Bell, 1981; Meehan, 1975). Aboriginal women were not visible to European men the same way that Aboriginal men were. Even European women in more recent times, such as Bell (1981, 2002), reported not being allowed access to information on several occasions. It is likely that Aboriginal women would not have wanted to interact with European men, especially if doing so infringed on their daily activities. Men were easier to interact with and observe, resulting in more description of their activities by Europeans (Eyre, 1845). The ability to record observations of Aboriginal women, alongside preferential treatment of men, is likely to be one of the main reasons women's roles are not as discussed in these early written accounts.

Because of this bias in the source material, we can examine what men did (or did not do) to understand what women did. Men are characterised in these early sources as being the hierarchical heads, emphasising the importance of male skills and activities (Spencer & Gillan, 1899). Men were deemed to have more complex religious rituals, were viewed as the only ones to partake in art, and were viewed as political figureheads (Spencer & Gillan, 1899; Hays-Gilpin, 2004). The most distinctive and well-known activity done by men is big-game hunting. Hunting was observed as an essential contribution to men's kin and ritual obligations, with interpersonal obligations predominantly occurring during hunting expeditions (Berndt & Berndt, 1999).

Such expeditions were a way to achieve prominence by providing for and contributing to the group (Altman, 1997). Like women's gathering parties, these expeditions were carried out solely in the presence of other men, and only during the evening did men re-join the women in a shared space (Kaberry, 1939). Hunting was represented in stories, dances, and rituals, and such activities were used either to represent hunting activities or aid in it. Eyre (1945) lists numerous songs used to aid hunting success, many of which are used in specific circumstances. Early accounts encompass the role hunting had in subsistence and wider cultural activity. This depth of perspective is missing from the writings of female activities during this period.

2.1.2 Archaeology

The absence of gender in sources, both past and present, only contributes to outdated ideas of the roles of Aboriginal women. Gender as an initial aim of Aboriginal Australian research is uncommon. Instead, it is often observed within the results and subsequently discussed. This influences how one can interpret analysis when gender unintentionally becomes a variable, and simultaneously exposes how vital a variable gender is to consider (Geller, 2009a). However, it is missing in ways that often appear thoughtless. 'Archaeology of Ancient Australia' written by Peter Hiscock (2008), which is viewed positively for its comprehensive analysis of Australian archaeology, is missing the terms 'gender' and 'gathering' from its index. This book is a recent publication yet does not discuss gender nor the role of women in Australian history in sufficient depth to warrant an index category.

In Australia, ethnoarchaeology is often used in relation to gender by studying Aboriginal divisions of labour. Means of production in Aboriginal society are often divided by age and sex (Allen, 1996), so ethnoarchaeology allows observations of such divisions and the possibility of inferring such information onto the past. Ethnoarchaeologists act in collaboration with indigenous groups, and the information shared and provided not only contributes to information about indigenous culture of both today and the past, but allows indigenous people to be in direct control of how their culture is shared (Atalay, 2012; Brady & Kearney, 2016). Perhaps the most well-known example of ethnoarchaeology in Aboriginal Australia is Betty Meehan's 'Shell bed to Shell Midden' (1975). She examines the division of shellfish gathering and the contribution of shellfish to diet. Focusing on the Anbara community living near the Blyth River, Meehan sought to examine divisions and organisation of shellfish gathering as a contribution to the local diet. In doing so, she contributed information that could be used to further understand numerous Midden sites in the surrounding area.

Meehan discusses divisions in subsistence activity by gender and the role that wider life events can have on such subsistence. This includes menstruation, pregnancy, and child-care (Meehan, 1975). In the case of males, only some carried out shellfish gathering as it was predominantly viewed as a female activity (Meehan, 1975). One aspect that stands out is 'successful food-procurers' have the same name by the Gidjingali regardless of gender. Women's collection of shellfish or tubers was held in the same esteem as the hunting of big game. Such knowledge provides an insight into divisions of labour of this community that would not have been learned from archaeology alone, and ensures that people are factored into an archaeological explanation. While ethnoarchaeology has been described as struggling to find its place in archaeological study, it provides valuable information that is hard to find, or missing from the archaeological record (Brady & Kearney, 2016).

1.2.1.1 Rock art

Aboriginal rock art has been one area of archaeological study in which gender and sex make an appearance. Australian rock art was initially presumed to have only been created by men, as observed by European colonists (Spencer & Gillan, 1899). Nevertheless, research has provided possible archaeological evidence of women and children's roles in its production (McDonald, 1992, 1995; Gunn, 2006; Drew, 1995). Distributions of hand sizes consistent with participation by women and children have been observed in numerous sites across Australia, creating an image of social, community events that are observable today (Gunn, 2006). Alongside hand size, the stencilling of tools in art by holding up a tool and spraying pigment over it was done not only with spears and other weapons but also using women's tools, such as digging sticks and dillybags (McDonald, 1995). While there is no definite way to prove the identity of the people who createdthe art, such studies display women's presence in cultural creation, and do so in a way that incorporates women as social and active participants in cultural activities.

However, there is an issue with using hand size as the sole indicator for sex. Due to variability in hand sizes across both age and sex categories, the reliability of hand size as an indicator of sex is very low. Flood (1987) measured the middle finger of stencils found in the Koolburra plateau to determine whether different sites were used by only one age group. Stencil measurements were grouped into five categories, from very small to very large. It was found that determining age or sex was not possible from measurements alone, except in the case of extremely large hands that were likely to belong to adult males. While McDonald (1992) relied heavily upon differences of hand size as indicative of the presence of different sexes, this does not mean that different sexes cannot be found. Flood (1987) concluded that different sites could be deemed 'family sites' due to a range of hand sizes, including infant hands and feet. Other sites, with larger hand stencils and images of 'Mythical Beings', were deemed to be male ritual sites. McDonald (1995), focusing on the Sydney region, found evidence of women's contributions by examining hand size and incorporating archaeological evidence tied to women's activities. This included fishhooks, shellfish, and small land mammal remains. Infant hands were also tied to the presence of women at these sites (McDonald, 1995). While hand size alone would be ideal, individual variation and wide margins of error mean the incorporation of other evidence is needed to determine who created rock art, and the dynamics behind its creation (Gunn, 2006).

Evidence as to who created rock art can also be found in the creation of figure paintings. Both female and male figures have been identified in numerous sites across Australia. In the absence of sexual identifiers, figures have been presumed to be male (Drew, 1995). There is regional variation in how female figures are painted and how they are painted in relation to males. However, female figures are often shown with breasts or vulva (Drew, 1995). In addition to female characteristics, many are also depicted with food gathering indicators (Bowdler & Balme, 2010). While initially presumed that the absence of sex markers insinuated a male figure, it has since been proposed that figures lacking sexual identifiers, or 'neutral' figures, are inclusive of both male and female figures (Green, 1997). Although art is not directly tied to gender or division of activity, it is essential to recognise where gender may become present and not inadvertently underestimate its importance in any facet of culturally driven activity. The presence of female figures suggests that art was not only a male domain as initially believed, and that even if only men created it, women were viewed socially important enough to be artistically represented.

2.1.2.2 Cultural Adaptation

While rock art reflects how people existed within their environment, the mid-Holocene indicates changes to that environment. It has been found that Aboriginal social structures and subsistence changed throughout this period to varying degrees. The archaeological evidence behind such changes has resulted in theories regarding how humans in Australia adapted to environmental change, and the role of subsistence within this. Two key ideas drove this debate: the intensification (Lourandos, 1980a, 1980b, 1983) and the risk minimisation (Hiscock, 1986, 1988b, 1994) theories. These theories, however, do not dictate the current understanding of changes throughout the Holocene (Ulm, 2013; Pate, 2006). While initially driving the discussion about changes in the Holocene, broader discussions of social change, subsistence methods, and environmental change have taken place.

The El Niño Southern Oscillation [ENSO] has been a driving force behind environmental changes throughout Holocene Australia. Approximately 5000 years ago an intensifying ENSO caused environmental and climatic changes across the continent, subsequently causing observable shifts in Aboriginal societies (Dilkes-Hall et al, 2020). These shifts include population changes, increased migration, shifts in tool use, and increased intergroup exchange and ceremony (Lourandos, 1983; Hiscock, 1986, Dilkes-Hall et al, 2020). While social change to this degree would have been impactful to many areas of life, the specific impact of environmental change is difficult to determine. The scale of effect would not be the same for all aspects of life. Increased migration, intergroup exchange, changing tool types and sedentism may result from social change, yet may not reflect economic or subsistence change nor indicate the scale of such changes. Through all these discussions, gender is left wayside.

Intensification was first proposed by Lourandos and is a theory that emphasises economic development and stabilisation of resource procurement. This was done by two main methods: (1) stabilising resource yields, and (2) managing or controlling resource regeneration (Lourandos, 1980b). During the late Holocene, there was an increase in new sites, and pre-existing sites saw intensified usage. This has been connected to an increase in progressively complex economies and traditions, alongside the Australian small tool tradition (Lourandos, 1983; Hallam, 1977). This theory proposes that in response to environmental change and subsequent population change, Aboriginal groups worked towards semi-sedentism and the cultural aspects that follow. This includes intergroup exchange and ceremony, increased competition, and increasing management of local resources (Lourandos, 1983). By ensuring group cohesion and increased social relationships, the possibility of stress is decreased should a turbulent environment once again occur.

The risk minimisation theory, proposed by Hiscock (1986), discusses that people sought to reduce food uncertainty by increasing flexibility in migration and subsistence patterns (Hiscock, 1994). Hiscock defines risk as being the probability of being unable to procure a resource, or what is defined as such (1994). It is the drive to lower energy costs when there is a chance of low foraging success that is thought to have influenced cultural and technological changes over this period. To reflect this, Hiscock used changes observed in the Australian Small Tool tradition throughout the mid-Holocene (Hiscock, 1994). Due to changing subsistence strategies, new tool types were created for multipurpose use, mobility, and strength in order to cope with uncertain food availability and foraging success (Hiscock, 1994). Hiscock later revised his theory to explain how tool change is only one aspect of cultural change in response to environmental change. Changing tool use further promoted identity signalling through monolith creation, and inter-group relationships and exchange (Hiscock, 2021). Changing tool use was only one aspect of regional cultural change that furthered adaptation to a changing environment. This theory speaks less towards an overall social cohesion discussed within the intensification theory, and instead is better suited towards regional and group variation in response to environmental change.

Between the risk minimisation and intensification theories, there is a discussion between overall and regional change as a response to environmental pressures. Ulm (2013) discusses local and regional variation in new tool use and migration and how the complexities behind this variation has yet to be completely understood. However, regional differences do not mean a lack of broader cultural exchange and contact – a difference which bridges the opposition seen in earlier theories. Littleton, Karstens & Allen (2021) propose something similar in the Murray region, in which the river acted as a means of communication and gene flow. Yet, people maintained distinct (if porous) boundaries and emphases. Balme & O’Connor (2016) also indicate how female subsistence may have changed throughout the Holocene following the introduction of the dingo. The use of the dingo as a subsistence tool would have improvedor the foraging success of small game, and affected broader social and cultural dynamics (Balme & O’Connor, 2016).

In the discussions surrounding social and economic changes across Aboriginal Australia, the consideration that gender acts within the same pressures as any other social phenomenon is missed. Environmental pressures and political or cultural shifts will affect gender, which will, in turn, affect activity, intergroup relations, and social hierarchy. While the relationship between all these factors would vary significantly between communities, it does reflect that as a social organiser and divider, gender should be playing a much bigger part. This is especially so in discussions regarding how a society may be affected in the wake of large scale environmental and social change.

2.1.2.3 Material Remains

When attempting to understand how Aboriginal women have been made visible through archaeology, the most prominent event for gender in Australian archaeology is the 1995 Second Australian Women in Archaeology Conference (Balme & Beck, 1995). While this was not the first, nor the last, it was a turning point for how gender was perceived in Australian archaeology, and how the study of gender contributed to furthering our knowledge of Australian history. This conference was the first organised discussion with gender at its centre, focusing on how gender contributed to Australian history throughout time. This conference highlighted that not only has the importance of gender as a variable been disregarded in past research, but in the context of Australia, the environment of Australian archaeology can make it difficult. Precolonial 'feminine' tools are often organic materials that are lost to time to a higher degree than 'masculine' tools.

When using material remains to examine gender in Australia, 'historical' archaeology rather than precolonial is often the focus. When research on gender in Australian archaeology is already limited, the stark absence of research on Aboriginal gender is made more obvious. Anderson (1995) pointed out three clear difficulties of studying gender in Australian archaeology. 1) Women are invisible in the record, 2) the record lacks objectivity, and 3) the record contains no reconstruction of the development of gender relations (Anderson, 1995). While Anderson applies the above statement to historical archaeology, it can easily be applied to precolonial archaeology. Not only did this mean that men's perspective of archaeological sites continued to be perpetuated, but that evidence of women in archaeological sites was often overlooked or its importance disregarded.

2.1.3 Bioarchaeology

Where archaeology fails and bioarchaeology picks up, is being able to examine the direct effects society has on the people within it. Embodied experiences on the skeleton allow us to use direct evidence of people's lives to make inferences about the past, and how their society may have changed and evolved throughout a lifespan. While studying human remains offers a breadth of new knowledge, one must be careful in how the analysis and subsequent results are handled, and how they can later be interpreted. Not only is there inherent bias in samples ofhuman remains, but the results reflect onto the people being studied. It is vital to ensure no harm is caused to the dead themselves or any surviving descendants. This is especially so whenusing indigenous remains.

Bioarchaeological study of Aboriginal Australia is limited, especially in the context of studies that focus on gender roles and divisions. The relationship between divisions of labour and sex influences how we can understand gender divisions in the past (Hollimon, 2011; Conkey & Gero, 1997; Geller, 2005). While many studies focus on differences between Aboriginal males and females (Kondo & Townsend, 2004; Carlson, Grine & Pearson, 2007; Margetts & Brown, 1978; Freedman, Blumer & Lofgren, 1991), these differ from the skeletal analysis of culturally driven changes between male and female skeletons. While differences between groups of a population are inevitable, by excluding the cultural drivers of such change, often such differences are absorbed as biological. Differences across groups are reported with little explanation as to their development. However, it is the development of these differences that is of interest.

2.1.3.2 Dental pathology

In Australia, one aspect of bioarchaeology that is continually focused upon is dental pathology. One common area of study that pertains especially to analysing divisions of labour is the study of dental wear and abrasions. Because many Aboriginal societies are known to use their teeth as a tool, analysing both macro-and micro-abrasions resulting from work can help us infer how people carried out labour at a community level, and how particular activities may have been distributed. Such studies, by analysing dental wear (Clement et al, 2009; Smith & Littleton, 2019), enamel defects (Smith, 2016; Goodman, Armelagos & Rose, 1984; Deter, 2009), and isotope analysis (Pate, 1998; Pate & Owan, 2014; Hard & Katzenburg, 2011), provide the ability to understand how diet or labour involving teeth use may vary across sexes. This providesnot only economic information but also social (Griffin, 2014).

Such analysis is not without flaws, however. The exact causes of tooth wear are often unknown, and like much of anthropological study, relies heavily on context. There is a known pattern of tooth wear on hunter-gatherer teeth, thought to result from powerful chewing, extensive lateral jaw movement, and an extremely fibrous diet (Watson et al, 2013; Smith, 1984). Aboriginal Australians have tooth wear that reflects this, but have the added factor of teeth as a tool. Teeth as a third hand was commonly observed in food processing behaviours, which at Roonka was likely to do with stripping sinews or processing materials (Littleton, 2017a; Trow, 2017; Pardoe, 1995; Littleton, Karstens & Allen, 2021). Consistency across tooth abrasions and wear can examine changes or differences within or across different groups, including sex or age categories (Littleton, 2017a; Trow, 2017).

Dental analysis in hunter-gatherer societies is often used to understand heterogeneous contributors to tooth attrition, including diet, occlusion, and non-masticatory use of teeth (Littleton, 2017a). Sex has been used to evaluate the extent of differences in diet, the use of teeth in food production and manufacturing, and what this could mean for social differences between the sexes. Thorne (1975), using cranial remains found at Kow Swamp and Lake Mungo, described differences in tooth abrasions as likely being a result of "the man-the-hunter and women-the-gatherer dichotomy" (pg. 92). This interpretation is justified by the assumption that women would have eaten more fibrous foods containing more grit than men's higher protein diets (Thorne, 1975; Webb, 1982). However, analyses of sex differences in dental wear are rarely categorised by age, often due to difficulties in assessing occlusal relationships as wear progresses (Littleton, 2017a), meaning that the progression of wear over lifetimes, as is suggested by Thorne and Webb, is not recorded. In hunter-gatherer societies where age is often an important factor for task distribution, this can act as a confounder to differences observed in sexes (Littleton, 2017a; Turner & Machado, 1983). Nevertheless, dental-wear analysis by age and sex shows marked intergroup variability and differences in wear change by location (Littleton, Karstens & Allen, 2021; Littleton, 2017a).

The patterning observed through dental wear reflects not only ecological zones and resources within them, but the economic organisation within those zones (Littleton, Karstens & Allen, 2021). Economic uses are non-masticatory and have been observed to play vital roles in activities that include net and basket-making, plant processing and food processing (Eyre, 1845; Kaberry, 1939; Trow, 2017). The differences between groups result from social differences in teeth use for such activities. This is the culmination of ecological and cultural action – both the resources available in the area and the use of those resources by the people.

2.1.3.3 Skeletal pathology

Compared to dental pathology, fewer studies focusing on skeletal remains have examined gender. Part of this is that there is a lack of large Aboriginal skeletal collections. Consequently, these reports are often the basis of knowledge regarding large-scale pathological differences between males and females. It is from such reports that gender can be inferred or analysed due to pathological differences between the sexes. This can include differences in stress response, trauma, nutrition, and general health that may indicate divisions in the treatment of different groups. While there have been few studies that contextualise divisions between the sexes in the context of differences in activity, information provided by skeletal reports does show that divisions of labour, and differential treatment of males and females, was widespread, yet variable across Australia.

Of these reports, Webb's (1981, 1982, 1984) work is the most well-known. Webb has produced in-depth analyses of skeletal collections across the Australian continent, and has provided analysis that allows for the comparison of these different groups. Although he is not the first nor only to do so, he is an example of how such pathological reports have allowed for continued analysis and discussion about Aboriginal human remains, and the subsequent embodiment of cultural activity over time.

In analysing differences between males and females, Webb concludes that females underwent greater amounts of stress across the continent compared to males (Webb, 1982, 1884). This conclusion is based upon higher overall rates of Harris lines and cribra orbitalia (associated with anaemia and other deficiencies) in females across Australia. Of all areas he analysed, however, the Murray region showed the highest rates of stress markers and the most unique in relation to other areas in Australia (Webb, 1982). Webb compares this to patterns seen in semi-sedentary societies, with people living in close proximity and high food production in heavily exploited resources (Webb, 1984). This is especially so when considering that Webb constructed his interpretations built upon biases that placed males as social and economic heads of society.

Although Webb denounces over-relying on early historical records to make inferences about Aboriginal health and well-being, he inadvertently falls into stereotypes set up by these early accounts. This includes presuming differential food treatment between males and females, and viewing the increased amount of cribra orbitalia in females to be a result of severe anaemia and parasites from a poor diet and overworking (Webb, 1982, 1984). These conclusions are based on the premise that females were subject to harsh treatment at the hand of males within their community. As briefly mentioned previously, older females across Australia are less visible in the skeletal record. This is common elsewhere around the world, but in Australia is also the result of differential burial and difficulties in sexing Aboriginal females (Donlon, 1994, Littleton, 1998). Webb concluded that this absence of females resulted from females dying at an earlier age from lifelong stress and poor treatment (Webb, 1984). These conclusions continue to negate females' social and economic role as contributing members of society, and perpetuate long-disproven theories about how women were treated across Aboriginal Australia.

Webb is not the only one to report the general poor health of females throughout Aboriginal Australia, with Thorne (1975), Sandison (1973a), and Prokopec (1979) all reporting similar trends. All report increased dental wear in females than in males, seen in different groups across Australia. This has been attributed to a more fibrous diet from gathering and eating throughout the day (Thorne, 1975; Prokopec, 1979), and the increased chewing of plant fibres in the production of textiles (Prokopec,1979). Prokopec (1979) discusses that females are less present in the record, which he interpreted as a lower total number of females than males across the Roonka population. However, as discussed previously, this is likely a result of sample and sexing bias. Of note, Sandison (1973b) contradicts Webb by discussing that the Murray region has a notable lack of severe trauma, degenerative joint disease and infection when compared to other groups in Australia. The reason for this was unknown, however.

Skeletal pathology does reveal that in relation to sex and gender in Aboriginal Australia, often the lives of females are relegated to fertility or motherhood. Individual case studies are often most reflective of this, as detail into burial context often provides more opportunity to make inferences about who a person was throughout their life. One example from the Murray region is “Ambiguity in the Bioarchaeological Record: The Case of ‘Euthanasia’ at Roonka, South Australia” by Littleton and Wallace (2019). The female discussed was originally assumed to have died as a result of euthanasia due to a difficult childbirth, yet was reanalysed by Littleton and Wallace. They concluded that it is likely that this female died as a result of violence, wherein her vulnerable state would have been less able to defend herself. Interpersonal violence is known to have been a common aspect of life, and it is likely this individual was a victim of it (Littleton & Wallace, 2019). Although this case was hypothesised as being a mercy killing, this initial hypothesis ruled out any other possibility of events, leaving evidence aside that could provide an alternative view about how women interacted with each other and their society.

Although the above example is only one, it reflects that interpretations of females are dictated by how people perceive their role as maternal figures. This issue continues today and often affects interpretations of paleo-pathological analysis. When analysing gender, one can fall into preconceptions about what that person valued about themselves or what is valued about a person. For women, this value is often fertility or maternity (Geller, 2009b). The consequence of this is when relying on pathological reports, aspects of a person's existence may be focused upon with little relevance to particular trauma or stress. While these pathological reports and individual case studies are extremely useful resources, the interpretation of such reports must be contextualised within existing preconceptions of the time it was created in. The biases within such analysis must also be approached and understood.

2.1.3.3 Biases of Sample

A significant issue in assessing skeletal remains is the inherent biases that exist within a skeletal sample. The Osteological Paradox, first outlined in full by Wood et al. (1992), is a collective number of issues raised relating to sample bias in skeletal samples. These issues are inherent in any study of the dead, so they are well-known, but outlining their impact is vital in knowing how such biases affected one's study. At its core, the osteological paradox addresses three key issues: demographic non-stationarity, selective mortality, and hidden heterogeneity in risk (Wood et al, 1992; Wright & Yoder, 2003). These issues note the interplay of factors that contribute to making the skeletal sample what it is. To simply describe it, skeletal samples do not reflect the full extent of people who suffered a particular pathology or those who died from it, nor is the sample statistically representative of the people who lived during a period.

Across Australia, older females are missing from the skeletal sample compared to the number of younger adult females, and younger and older adult males. Webb (1984) theorised that this difference was likely due to females dying at a younger age as his pathological analysis concluded that females, on average, experienced higher overall stress compared to males of the same population. Webb also did not consider how differential burial location and burial type may have played a role in this difference (Littleton, 1998). Australia also has a sampling bias due to bone robusticity, which means females are less likely to be identified compared to males (Donlon, 1994).

The Murray Black collection, once the largest accumulated by a single collector, exemplifies the biases that can occur within a sample beyond those laid out in the osteological paradox. This collection lacks temporal or spatial control, and has isolated remains due to the excavation processes (Robertson, 2007). Fragmentary remains were not excavated, and if complete skeletons were excavated, they were chosen to be part of the collection based on their pathology or anatomy (Robertson, 2007). Post-contact remains were also actively ignored as part of the collection. Although the Roonka site does not have biases to the same extent as the Murray Black collection, the biases that can exist beyond those that are inherent have potential ramifications for skeletal analysis.

2.2 Ambiguity of Evidence

2.2.1 Fixed roles in Aboriginal Labour

When trying to understand how labour was divided, ethnohistoric accounts discuss significant flexibility in economic roles. However, this flexibility is something that escapes many interpretations of hunter-gatherer labour. The best way to understand what was acceptably flexible is to understand where roles were fixed, and how this may have differed among different groups of people.

Biographies written in the early to mid-19th century describe the roles of men and women as fixed, and fitting into preconceived notions about gender and labour. However, evidence combined from ethnographic reports, dental pathology, and skeletal analysis show that not only was 'gendered work' flexible throughout lifetimes, but there was substantial regional variation in this flexibility (Meehan, 1975; Berndt & Berndt, 1964; Bell, 1983). Throughout the Murray region alone, there is variation in dental markers of activity, with upriver showing distinct patterns between males and females, and downriver at Roonka, dental wear attributed to activity is homogenous and indistinct between the sexes (Littleton, Karstens & Allen, 2021). While the environment will play a role in this as different needs require meeting, how different activities are deemed flexible is ultimately the result of cultural norms across communities.

Ethnographic accounts detail that the only area of Aboriginal life as truly inflexible is ritual or religious spheres (Bell, 1981; Berndt & Berndt, 1964). This division is significant and intentional and ensures that social, physical, and spiritual order is maintained (Bell, 1983). The consequences of flexible economic work are far less than flexible religious work. Ritual spaces are clearly divided by gender. Entering this gendered space uninvited is considered a massive insult, not only to the people whose space was violated, but also to the ritual being carried out (Bell, 1981, 1983). Economic work is similarly divided by space, with subsistence activities being carried out away from the communal areas before people regroup later in the day. The social aspect is gendered and inflexible, yet the actual activities remain opportunistic.

2.2.2 Divisions of labour

One significant issue of looking at the distant past in Aboriginal Australia is the absence of primary sources beyond archaeological and bioarchaeological evidence. As a result, gender can only be inferred rather than directly observed (Geller, 2009a). Not only does this mean that we are reliant on post-settler sources, as mentioned above, but such sources were created often several thousand years later than the time being studied. Defining gender as a concept in a culture that is understood only at a distance is almost impossible. Yet, the definitions of gender are as flexible as the rest of the culture it is a part of. The implications of gender extend to social hierarchy and religious practice, yet division of labour is an aspect of many societies that remains heavily biased. These biases often stem from a place of male hierarchy and limits how we can understand a society if one does not attempt to overcome those biases.

In precolonial Aboriginal Australia, our knowledge of subsistence was built upon biases about gender and labour. Breaking away from these assumptions has provided new insights into how Aboriginal societies varied from each other, and in what ways activity was gendered.

While ritual saw fixed roles and economic labour saw some division, determining how and where such activities stop being divided by gender is difficult. Although there are accounts of men and women doing tasks together, such as Eyre (1845) describing men and women fishing together, this is different from the organised expeditions of work encompassed in women’s work and men’s work. Some have described that Aboriginal divisions of labour fostered interdependence and independence of the genders, and did so in a way that many early sources neglected to observe or understand (Bell, 1981; Berndt & Berndt, 1964). Divided labour meant that people were reliant on each other for specific foods or rituals that were grouped by gender or age. This sentiment goes against how many early male anthropologists viewed the relationship between genders, and is an interpretation that does not emphasise an inherent hierarchy. Divisions of labour by gender meant people were given freedoms and movement in an Aboriginal community in a way that early European colonisers did not appear to grasp or discuss.

2.2.3 Flexibility of Roles

Multiple accounts of Aboriginal labour divisions point to flexibility in so-called “gendered activities”. Balme and Bowdler (2006), C. H. Berndt (1970), and Kaberry (1939) all point out that all genders carried out hunting and gathering activities to some degree. While these are ethnographic observations, such patterns of variation have also been observed in some bioarchaeological analyses. With physical observations of people, what activities are carried out by different groups, and the extent to which they are carried out, can be observed (Meehan, 1975). When using skeletal remains, this benefit is missing, and instead, while the presence of flexibility can be observed, there is no indication of specific activities that individuals carried out. Understanding flexibility in the bioarchaeological record, and how this could influence how markers of activity present themselves in the sample is subsequently difficult to discern. Although flexibility of subsistence roles has been observed and hinted towards, it is often regarded as regional variation as to what activities are gendered or not. However, this means that our interpretations of labour remain gendered. Because of the potential lack of a clear division in labour between the sexes, when attempting to find gender, what the binary is and examining how people may have fallen along it can become clouded.

Not only affecting the bioarchaeological record, the image of ‘Man the Hunter’ is so prevalent that implicit assumptions that follow this model ignore the possibilities of role swapping, sharing or overlap (Anderson, 1995). Gendered work being carried out was done so in such a way that people understood their roles; both concerning themselves and other genders, but also to the relationship work had with wider cultural constructions. Because of this flexibilitypeople knew how their place in society was constructed and where it was important to uphold division. The flexibility of men's ritual work or women's ritual work would have far more consequences than carrying out hunting or gathering (Bell, 1981).

2.2.4 What questions are there

Because of how gender is understudied in archaeological and bioarchaeological contexts, there is an unbalanced understanding of Aboriginal gender roles and concepts. This in turn limits our understanding of Aboriginal economy, subsistence patterns, social structures, and intergroup relationships. Being more complicated than looking at the relationship between, or the roles of different genders, gender is a highly significant factor in all aspects of cultural life. The aim of this chapter was to examine what we know about Aboriginal gender and how we know that. This in turn begs the question of why gender is important to study and what does studying it contribute. The answer is yes, gender is important to examine and study. Social organisation is largely constructed by how people separate themselves, and gender is one of the most visible and recognisable forms of separation (Maharaj, 1995). To brush past it as simply nothing more than women's work minimises its role and stunts future study of social organisation and labour.

Aboriginal Australians viewed gender as an integral aspect of daily life, and how one feels about their gender plays a primary role in their position in a society and what roles they undertake. When examining this in a bioarchaeological context, patterns of activity can be contextualised alongside the people they are surrounded by in death, and their sex can be examined. Often gender is silenced in this. By examining gender specifically, it becomes easier to find those outside of a binary, and it ensures that a gender binary is not ascribed to. To provide identity back to the people who have lost that aspect and highlight the complexities of the community being studied, gender is vital to understand and apply within bioarchaeological contexts.

Chapter three: Roonka Flat

This chapter will discuss the site that this research will focus upon, Roonka Flat, and situate the wider research addressed in chapter two within the Roonka site.

3.1 The Site – Roonka

3.1.1 Site ecology

Roonka is located along the Murray River in South Australia (Fig. 3.1). The Murray-Darling riverine system, upon which the Roonka site is located, is the largest permanent riverine system in arid Australia (Overton & Doody, 2013; Murray-Darling Basin Royal Commission [MDBRC], 2019), and provides an abundance of variation in exploitable resources.

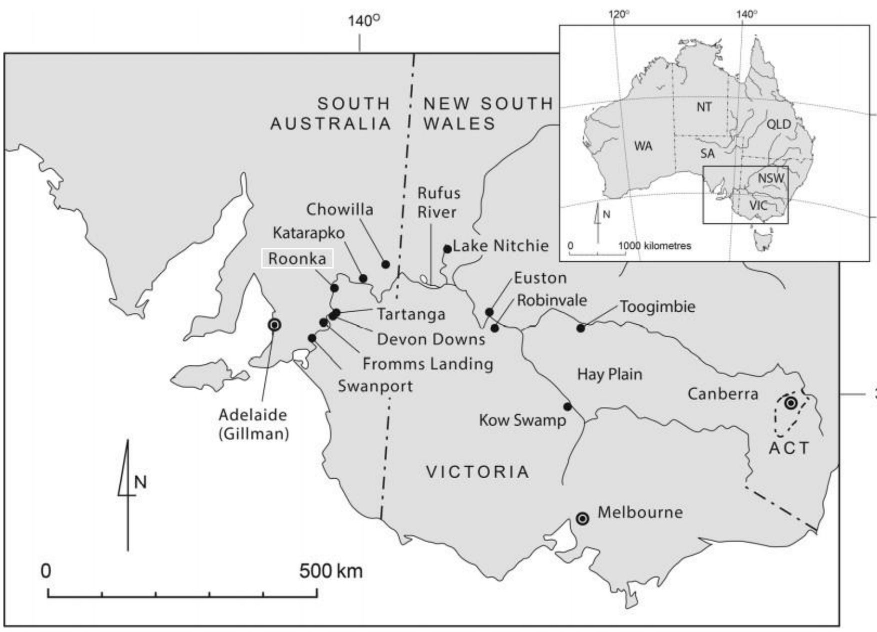

Figure 3.1 - Map showing the location of Roonka in the Lower Murray River Valley of south-eastern Australia (modified from Littleton, 2017a).

Roonka, more specifically, is located within the Murray Gorge, an area approximately 1.25km wide and 30 metres deep through which the Murray flows (Pretty & Kricun, 1989). Because of the gorge depth and the relative reliability of the river stream, the gorge creates a contrast between the biomass rich valley bottom, and the diminished semi-arid scrub of the elevated plains (Pretty & Kricun, 1989; Pretty, 1988; Bowler & Magee, 1978; Foulkes and Gillen, 2000; Laut, 1977). Over time, the Murray region saw a change in environment coinciding with a strong shift in the El Niño Southern Oscillation (ENSO) in the mid-Holocene. The environment of the Murray region pre-ENSO was warmer, wetter, and more stable, with large Eucalyptus forests forming as a result of high precipitation (Pretty & Kricun, 1989; Kershaw & McGlone, 1995; Helfensdorfer, Power & Hubble, 2020; Gouramanis et al, 2013). Post-ENSO, arid Australia became drier and more unpredictable with increased droughts and lower river and lake levels (Quigley et al, 2010; Shulmeister and Lees, 1995; Kershaw & McGlone, 1995). This change in the environment affected subsistence strategies and what resources were available overtime. However, a large Aboriginal population was observed along the Murray, with people living along the river's entire length (Eyre, 1845). The mix of environments and the available food sources found within it meant that even with environmental stresses, the human population and migration around the area remained substantial relative to other parts of Australia (Eyre, 1845; Pretty, 1977; Littleton, Karstens & Allen, 2021).

Observations of diet highlight roots and shrubs, fruits, honey, grubs, birds, snakes, lizards, fish, mussels, and macropods (Eyre, 1845; Littleton, Allen & Karstens, 2021). Isotopic analysis at Roonka supports this mix of terrestrial and marine diet; however, it must be noted that there are some differences in what comprises the main components of the male and female diets in the area (Pate, 2000). This mixed diet facilitated different methods of securing resources, and while these practices varied on location, in Roonka these were fishing, trapping, foraging, spearing, and the creation of rope, baskets, and weapons (Eyre, 1845; Broome, 2017). How such tasks were distributed across the community would have varied depending on cultural expectations of different ages or genders, subsequently affecting subsistence strategies and social organisation.

3.1.2 Excavation

Due to attempts at agriculture in the area, and after a series of floods and drought, the destabilisation of soils resulted in the discovery of human remains along the river (Prokopec, 1979). Roonka underwent extensive excavation by Graeme Pretty from 1968 to 1977 (Pretty, 1977). The site was discovered to have 216+ burials, and shows a diverse range of burial types and cultural materials (Pretty and Kricun, 1989; Pretty, 1977). Consequently, it is recognised as the largest and most complete excavation of an Aboriginal burial ground in Australia (Littleton, 2017).

This is in part because dating of the site shows continual use from the early Holocene to the early colonial period (Pretty, 1977). As a result, the site provides the rare opportunity to understand temporal changes over time in site use and in local occupation of the area (Littleton et al, 2013). Because of the span of use at the site, it has been theorised that the Roonka burial site could be indicative of the intensification of Aboriginal society in the area. This is due to a combination of changing burial types and the material found in the area, evidence of possible sedentism, and intentional control of resources (Lourandos, 1983; Hiscock, 1994; Ulm, 2013). This debate has many perspectives about the use of the site, and the implications of this on interpretations of the skeletal remains found at Roonka.

The site was initially grouped into four periods of site use: I – Pleistocene (older occupations), II – "Necropolis" (7000-4000 BC), III – occupation and burial (4000 BC-AD 1850), IV – post colonisation (Pretty, 1977). Redating of this site by Littleton et al. (2017) finds five periods of periodisation (Table 3.1). Redating puts the possible beginning of site use at around 10,000 BP, with the first burials being 7000 BP (Littleton, Walshe & Hodges, 2013; Littleton et al, 2017). This reconsideration of site use through redating suggests episodic use of the sites and heterogeneity in burial practices over short periods of time (Littleton et al, 2017). Periods A and B show predominantly male burials or children with infrequent or absent females (Littleton, Karstens & Allen, 2021; Littleton et al, 2017). The later periods (C & D) at the higher excavation levels have almost equal female inhumations by the end of Phase II. These upper levels are also where the range of burial type increases (Littleton, Karstens & Allen, 2021). While this site shows a stable sex ratio in total counts of individuals across sex categories, this is a result of time-averaging. While never ideal, time-averaging does allow for a general understanding of the site, and in the case of examining gender, allows for larger sample sizes that would otherwise be limited by time.

Table 3.1 - Redated periodisation of Roonka compared to Pretty (1977), adapted from Littleton et al. (2013)

Dating BP (Based on calibrated C14 dates (see Littleton et al. 2013))	Roonka Project	Pretty	Layer	Roonka project criteria for assignment	Pretty's criteria for assignment
Post-contact	E	IV	1/2 upper	date or evidence of post-c.	upper sterile layer or evidence of post-contact
340	D	IIIB	2	in upper level 2, level 2 fill or association with dated burial	Level 2 or upper level 3, level 2 fill (if visible), and flexed or extended
1350	MCA	---------			
2000	C		2	in level 3, level 2 fill or association with dated burial	
4000-		IIIA			Level 3 and recumbent contracted
					Level 3 and fully extended or erect, lower half of level 3, manganese staining,
4870	ENSO				
5460	B	II	3	in level 3, level 3 fill or association with dated burial	
6600	GAP				
9710	A		3 AND 4	in lower level 3 or 4 with level 3 fill or association with dated burial	
Pre-9800		1	Base level 3		

3.1.3 Intensification debate

The central and lower regions of the Murray River were some of Australia's most densely populated regions, meaning the intergroup relationships and exchange thought to drive social complexity are likely to have played a prominent role in the social development of this region (Pate, 2006). The long-standing and seemingly stable population over thousands of years was ideal for examining changing social structures and intensification. At Roonka, the intensification debate largely rests on how site use was divided and organised. Roonka was initially chronologically organised by burial type, as it was theorised that as the site intensified burial methodology simultaneously increased in complexity (Pretty, 1977). However, that has changed since burials were redated to show that some burial methods were used concurrently (Littleton & Scott, 2016; Littleton et al, 2017). Isotopic evidence for sedentism (Pate, 2000, 1998; Pate & Owen, 2014), evidence of exclusive site use (Pardoe, 1988), and evidence of changing health and population levels (Webb, 1982; 1995) have all been theorised to contribute to the possibility of an intensifying Roonka site.

However, many of these theories are based upon the chronology of burial type. Pardoe (1988) furthers this by suggesting that the presence of well-defined cemeteries along the Murray acted as a form of boundary maintenance for groups in the region, and these cemeteries are defined by burial type and location. However, not only did people move away from an area after it became a burial locale, but the clustering of burials with distinct burial positions along the Murray suggests that different groups used the same location as a burial site (Littleton & Allen, 2007). Although the Murray has been treated as an area that best shows changing intensification, the risk minimisation theory has been applied to Roonka more specifically by Hill (2016, 2019, 2020). At Roonka, this is the establishment of lowering costs of food production in the face of ecological and social stress (Hill et al, 2016). Yet, Hill et al. (2019) relies on the assumption of burial type changing over time to dictate his interpretation of site chronology, contradicting his denial of intensification. This issue surrounding burial type and intensification has followed the analysis of intensification at Roonka, and continues to play a part in dictating how the site has changed over time.

Many sources that suggest a distinct intensification of the Roonka site in comparison to other locations are dependent on archaeological and ecological evidence. Theories regarding the intensification of Australia that have developed since the debate of the 1980s, tend to fall in line somewhere between the two original theories. Ulm (2013), previously discussed, argued that environmental change as a result of ENSO drove adaptive cultural change. The Murray region is amongst areas that show increased mobility due to decreasing amounts of critical resources. This subsequently results in other behaviours that conclude resource stress (Williams et al, 2010). In the overarching theory of intensification, gender continues to be pushed aside. The culture of a community and how work was perceived would affect how different communities responded to outside stressors. In forgetting where and how a society may be most divided, understanding social response to change may be harder to grasp. Within this is where the importance of gender lies.

3.2 Paleopathological work to date on Gender at Roonka

Although gender is recognised as a significant influence over social organisation or change, Roonka (like many other Aboriginal sites) is limited in the number of studies that examine gender. However, some studies have indicated socially driven differences between the sexes. Such studies can contribute to how gender can be understood, and as such, the studies on gender there are offer various interpretations of labour. Nevertheless, differences between sexes do not equate to gender differences, with such information being non-specific or an incidental discovery. Only one author has focused directly on gender at Roonka and the impactof gender on labour and social organisation.

3.2.1 Stable Isotopes and Trace Elements

Pate has done a significant amount of work on isotope analysis and trace element strontium analysis on the Roonka populations. While Pate never focuses directly on gender, his work often results in the comparison and discussion of differences between males and females, and how isotopes could be affected by such differences.

Pate applied trace element research to Roonka through strontium concentrations (Pate, 1984). Further research into trace element strontium subsequently found that strontium could not be related to past diet due to post-mortem chemical changes caused by the interment area, and such data could be affected by preferential burial location (Pate & Brown, 1985; Pate, Hutton & Norrish, 1989; Pate et al, 1991). Isotope analysis later carried out by Pate (1998a; 1998b; 2000;

2006) found that in the late Holocene, females had a lower δ^{15}N value in bone collagen compared to males. This indicated that females had a diet largely comprised of terrestrial plants and freshwater foods, whereas males had a diet more comprised of terrestrial mammals and freshwater fish. Subadults are also shown to have similar bone collagen patterns to females, showing that subadults likely spent more time with females during the day (Pate, 2000; 1998a). Pate concluded that these results show dietary differences between males and females that indicate food-sharing, if practiced, did not result in equal distribution of food types.

When attempting to specify what food composed the diet at Roonka, the results of isotope analysis could not distinguish between freshwater fish and shellfish, and terrestrial mammals. Pate focuses on δ^{13}C and δ^{15}N stable isotopes at Roonka, and it is the nitrogen isotope that confuses these results (Pate, 1997; 2000). The nitrogen isotopes were attributed either to ^{15}N-enriched terrestrial plant and animal foods from the surrounding plains, or ^{15}N-enriched aquatic foods from the river (Pate, 1997). These isotope results can be further questioned when considering carbon in freshwater environments. Isotopic signatures of consumed fish can vary based upon where and what season the fish are caught (Cartwright 2010; Hardy, Krull, Hartley, & Oliver 2010). Pate recognises the limitations of isotopic analysis in the Murray region by reiterating that continued focus and analysis are vital to understanding isotopic variability (Pate, 2017).

While no work by Pate specifically discusses gender in relationship to isotope analysis, ongoing research by Karstens addresses this issue. There is evidence of cultural practices behind food variation within a community, including foods with age or gender restrictions (Littleton, Karstens & Allen, 2021). Roonka provides the ability to examine gender better than most other Aboriginal Australian sites due to the proportion of female individuals at the site. While it is not yet a focus, with continuing developments in isotopic understanding and a growing interest in gender in Aboriginal Australia, this area will only increase our knowledge of food and dieting practises, and how social structure or organisation may influence this.

3.2.3 Long Bone Morphology

Of the research that surrounds divisions of labour and possible gender at Roonka, Hill is one of the most explicit in terms of specifying sex and gender as a driver for socially-driven changes in the skeleton at Roonka. This is most clear in two studies conducted by Hill (2019, 2020). However, when comparing these studies, they highlight the difficulty in analysing what could drive skeletal differences between the sexes.

Using the risk minimisation and the intensification theories, Hill et al. (2019) seeks to understand which theory is more plausible in explaining changes observed in the area, and how this is reflected in patterns of activity across the male and female populations. By examining upper limb robusticity and bilateral asymmetry, Hill et al. (2019) observed that males had higher bilateral symmetry and limb robusticity rates than females prior to the ENSO period. Yet, after the ENSO period, while male patterns remained relatively stable, there was an increase in female limb robusticity and bilateral asymmetry. This suggested an increased reliance on female subsistence methods due to the stability gathering provides in relation to hunting. It also suggests that while the social value of female subsistence methods increased, male activities likely had an unchanged view, or were seen as less valued as a subsistence method. Given the importance of hunting in inter- and intra-group relationships, it is possible that hunting continued as a social and ritual obligation while its role as a subsistence method lessened.

Just like Meehan's (1975) observations discussed in the last chapter, it is likely that gathering and small-game hunting widely conducted by women was likely to be held in similar esteem to big-game hunting conducted by men. As gender can be easily affected by broader social changes, it is possible that due to a decrease in big-game hunting success and an observed increase in reliance on women's gathering, that emphasis was then placed on the role of female subsistence. While this study does not examine gender specifically, it displays the role and importance of women's contributions to subsistence. However, the sexual division of labour is secondary to understanding changes over the Holocene. While the role of differing subsistence strategies is discussed, it is not contextualised within gender, only sex.

Unlike the 2019 paper, Hill et al. (2020) does not examine change over time, but has a general approach to the division of labour at the site. Hill et al. (2020) compared cross-sectional geometric properties of the humerus, radius, ulna, femur, tibia, and fibula, and examined differences in the upper and lower long bones. For the lower limbs, males and females show a similar pattern of moderately high diaphyseal rigidity and shape. This contrasts with the upper limbs, where females and males differ as males have moderately high rigidity and bilateral asymmetry, whereas females have low. Hill et al. (2020) interpreted the differences in the upper limb bones between the sexes as indicative of differences in the division of labour.

For females, the skeletal markers indicated bimanual loading – with likely activities being the use of the digging stick and grindstones, and a wide, low-effort subsistence method with the absence of focused exploitation of any particular resource (Hill et al, 2020). Males show the use of unimanual tools while hunting, including spears, boomerangs, and clubs. There is a lack of evidence for repeated throwing motions, contradicting ethnographic and Neolithic patterns of subsistence activity, so while this continues to be unexplained by Hill et al. (2020), there is a possibility that the role of fishing and net-use also affected the bilateral symmetry of the male population. Although some bilateral symmetry was found in Roonka males, it is only moderate, and Hill et al. (2020) suggests mixed subsistence strategies alongside big-game hunting and unimanual activities.

Along the river, with a diet primarily comprised of aquatic foods, fishing and net-making would have been extremely important and regular activities (Eyre, 1845; Trow, 2017; Meehan, 1975). While seed-grinding has been found along the Darling River, there is little evidence of it at Roonka (Fullagar et al, 2015; Littleton et al, 2013). The activities Hill et al. (2020) interpret from this analysis do not appear relevant to a riverine community. While trying to explain differences in activity between the sexes, Hill neglects to contextualise such results withinthe area in which he is studying.

Although both Hill et al. (2020) and Hill et al. (2019) focus on differences between males and females from the outset, these studies highlight the difference shown when comparing population change over time to a grouped sample. The 2019 paper, while discussing the roles of females and males, highlights how such roles may have changed over time, and how the importance of such roles may have changed. However, the 2020 paper, stepping away from change over time, discusses how such roles differ in the first place without broader social or environmental factors being considered. This difference in focus changes how one interprets divisions of labour and the inferences that are made from these different approaches. The types of activity carried out, and the wider social context of those patterns intersect with our understanding of labour in the past. These studies interact with those understandings of activity differently and subsequently affect each interpretation of labour.

Hill also uses temporal divisions based upon older dating sequences created by Pretty (1977), in which site dates are based on burial type. Littleton et al. (2017) revised such dating methodology and highlighted the issues behind using it. This means that studies conducted by Hill et al. (2019) are limited by their dating due to the use of an older, outdated chronology. This chronology also feeds into the idea in which this site reflects intensification over time, even though Hill et al. (2019) rejects the intensification theory as part of the site chronology.

3.2.2 Dental Analysis

While predominantly focusing on dental analysis, Littleton does impart information from which gender can be understood. Focusing on dental wear, Littleton (2017b) found that when comparing ethnographical sources and patterns of wear, females were observed conducting a significant amount of extra-masticatory work. The patterns of wear between males and females are remarkably similar compared to other areas of Australia (Littleton, 2017b; Littleton, Scott, McFarlane & Walshe, 2013). While females were found to have more variation in wear patterns, the difference between males and females remained slight (Littleton, 2017a; 2017b). In relation tosex differences, Littleton has also analysed age in relation to patterns of wear in the Roonka population, and found that wear develops quickly and increases with age (Littleton, 2017a).

Not only does the above information reflect the extra-masticatory activities carried out at Roonka, but reflects how sex may play a role in such activities. Littleton has found few differences between the sexes that suggest clear divisions of labour (Littleton, 2017a). As observed through dental wear, the variation in juveniles is the likely result of increased freedoms in activities and learning opportunities. Though these learning opportunities would have been different due to the different life stages of young boys and girls, there is still no significant variation between the sexes reflective of variable living circumstances and skill acquisition (Littleton, 2017a). This slight variation in young adults disappears in the middle adult categories, likely due to increased shared responsibilities felt by adults of the community. At this life stage, there continued to be no significant differences between the patterns of wear and activity across sex categories. While this sample is grouped by time and thus does not examine variable changes to gender roles over time, such studies reflect how gender may or may not be found. Dental wear is one area of pathological analysis, and it creates a precedent for what other differences there may be and how they relate to the absence of differences observed here.

While Roonka reflects few statistical differences across dental wear of sexes, upriver towards Euston, there are stark differences in the wear of males and females. This is especially observed in the flat wear plane of the anterior teeth, where females show much more variability in tooth wear patterns than males (Littleton, Scott, McFarlane & Walshe, 2013). This regional variation reveals differences in gendered activity across communities and that similar communities along the same river, such as Euston and Roonka, will have a culturally dictated response to surrounding resources that then becomes evident through these variations.

3.2.4 Dental microwear

Trow (2018) focused on dental microwear to analyse differences in male-female activity patterns, and how this correlates to patterns of labour represented in early historical accounts. By analysing variation in dental microwear, Trow concluded that males primarily conducted stuff-and-cut activities. During meat processing, hide was held in the mouth as a third hand while cutting meat (Trow, 2017; Kruegar et al, 2019). Aside from the striations evidencing 'stuff-and-cut' there was little other evidence to suggest a clear distinction between male and female activities in terms of extra-masticatory activity. The creation of materials such as ropes and twine, and the stripping of hides were determined to be activities that were likely done across the group, with everybody contributing to the creation and care of such materials. The research provided by Trow falls in line with other dental wear analyses of Roonka (Littleton, 2017a). It describes that in the absence of other markers, extra-masticatory behaviour is not divided by gender. Trow does recognise that dental wear has its limits as an indicator of activity and, as such, can only play a part in understanding gender or divisions of labour at Roonka.

While different from subsistence labour, such results do show variation in activities deemed 'gendered', and that in many ways, gender and age coincide to influence who undertakes particular tasks (Littleton 2017a; Garroway, 2012). While attempting to understand divisions of labour between males and females, Trow used five sex categories and the differences of microwear between them. The inclusion of probable male, probable female, and indeterminate are reflective of an expanded sex identification based on morphological skeletal features, and reflect not only the variability of, but the proportion of individuals who cannot be accurately sexed to be 'definite'. However, in this sample, these expanded sex categories were used as a reflection of intersex and non-binary individuals.

An issue that arises in Trow's study is the interpretation of how gender and sex relate to one another. While attempting to step away from the assumption that biology equals gender, Trow appears to assume that skeletons of indeterminate sex or probably sexed individuals were non-binary in their gender identity. The issue of this, similar to the assumption of a gender binary, isthat it assumes a gender identity when there is no presence of one. While all the people whose skeletons are unable to be determined as a sex would have existed within the realm of a gender identity, what identity that was cannot be assumed solely upon skeletal evidence.

3.3 Outstanding questions

3.3.1 How do these current studies agree?

Early sources, such as Eyre (1845), suggest stark differences between the activities of males and females, from the perspective of males as the hierarchical head. Later ethnohistories or ethnographic studies found that while there were broad differences between male and female activities, flexibility in the carrying out of these made it difficult to discern where much of the division lies (Balme & Beck, 1995). The studies examined here generally agree with these observations of activity. While most ethnographic accounts or studies do not come from Roonka, they still provide a valuable perspective that can be useful when analysing the differences seen throughout this chapter.

Many studies addressing the division of labour at Roonka highlight that the differences between males and females include diet, activity, and general health. This includes Hill (2019, 2020), who suggests that there are stark differences in skeletal patterns of activity, and Pate (1998a; 1998b; 2000; 2006), who found differences in diet that (if further examined) could indicate time spent throughout the day and how diet would contribute to this. However, Trow (2018) and Littleton (2017a, 2017b) show there is very little difference between females and males in terms of activity at Roonka, and that such variation suggests that gender roles and divisions of labour were not fixed. The remaining question is how such studies and interpretations interact and whether they correlate to any degree. The publications discussed above all have slightly differing perspectives on how life varied between the sexes, and how such information remains upon the skeleton.

The differences observed exist but overlap, and can be used in tandem to further our understanding of labour and how it was divided across the community. Trow (2017) and Littleton (2017a) found no significant difference between the sexes via dental wear. Yet, these results can still work with the results of other studies given the different natures and conclusions found. Littleton, looking at different methods of dental wear, Pate examining isotope analysis, and Hill examining cross-sectional geometry all tell slightly differing versions of the same story. Differences between the sexes at Roonka seemed slight and dependent on age, environment,and variations behind gendered activities. In this regard, these sources do agree with one another. There are consistent differences between sexes in some ways, and in others, there are not. Yet, as gender has rarely been directly looked for, how it becomes visible throughout thesesources is another matter.

3.3.2 What areas of information are missing?

That these studies are the ones most reflective of gender in Roonka shows that the study of gender itself is missing. Studies used by Hill, Pate, and Littleton all highlight differences between the sexes, but none address gender specifically and how gender fits within such interpretations. This is not a criticism of their work, as gender is a specific area of focus, but that these studies are what must be used to understand gender in an area shows how limited work on gender is. Trow is the only study found that specifically focuses on gender, and the variation across the population that may correlate to gender divisions and interpretations. As this literature is limited, the only way to address or solve such a gap is for more people to publish on such a topic.

3.3.4 What could be done to understand gender more?

While it is difficult to understand the full scope of gender at the site from such studies alone, these studies show the extra difficulty in interpreting and discussing gender in past Aboriginal societies. As precolonial records of gender are non-existent, gender interpretations about the distant past rely on modern sources and archaeological and bioarchaeological evidence. Contemporary sources on gender, written by Aboriginal authors, are limited and often discuss events of the 20th century, with the distant past being left out or discussions of gender being forsaken for discussions on sexuality.

Roonka, as one of the largest skeletal sites in Australia, provides a relatively stable total sex ratio, and therefore is an ideal site to examine divisions of labour and sex, and the role of gender within this. Ethnoarchaeological and ethnographical studies of the late 20th century that have been so vital to supporting our understanding of women's work, still exist within a western image of gender. To further our understandings of gender in the past, examining work done by Aboriginal people about gender and looking more deeply into the impacts of colonialism on traditional gender roles, would support changing our perception of gender in Aboriginal cultures (Clark, 2015). However, bioarchaeological evidence and patterns can be used and analysed alongside Aboriginal perspectives to further our understanding of gender. By attempting to find gender in the first place, our understanding is already being furthered.

Chapter Four: Osteoarthritis

This chapter will address osteoarthritis (OA) as a pathological condition and address its use in analysing lived experiences from skeletal remains. This includes how OA has been defined, how that definition has changed over time, and what this means for analysing OA in a paleopathological context.

4.1 Defining Osteoarthritis

Osteoarthritis is one of the most well-known skeletal pathologies and has been repeatedly used to understand activity and lifeways of populations around the world (Merbs, 1983; Molnar, Ahlstrom & Leden, 2011; Lieverse et al, 2007). For this reason, it was chosen as the primary method of examining possible patterns of gender at the Roonka burial site. There are difficulties, however, in interpreting OA in this way.

While there is no universally accepted definition of OA, there are factors that are agreed upon. No matter the term used, whether it is degenerative arthritis, osteoarthrosis, or degenerative joint disease, all terms point towards an eventual and progressive decline in joint quality (Waldron, 1997). What sets OA apart from these terms is that there is an inflammatory response not seen in other bone degenerative pathogeneses, alongside a reparative response as well (Waldron, 2009; Berenbaum, 2013). The process of OA has been described in three stages of pathology: 1) breakdown of articular cartilage, resulting in bone-on-bone contact and abnormal abrasion, 2) reactive formation in the subchondral compact bone and the trabeculae, possibly associated with cyst formation; and 3) new growth of cartilage and bone at joint margins (Ortner, 2003). It is a breakdown of relationships between articular components and in living people results in pain, inflammation, and joint instability (Winburn & Stock, 2019). To recognise it in deceased people, macroscopic indicators of joint damage or change have to be relied upon (Winburn & Stock, 2019; Jurmain, 1990).

OA is broadly defined as the degeneration of synovial joints, causing inflammation and joint space narrowing, which results in eburnation, pitting, osteophytes, and bone remodelling

(Molnar, Ahlstrom & Leden, 2011; Rogers & Waldron, 1995). While OA is difficult to define and subsequently discuss, it is important to maintain a standard approach throughout a study. Not only can joint damage be attributed to different names and pathogeneses, but damage can affect different joint types in different ways. While there are various types of arthritic degeneration, synovial inflammation is integral to OA. This inflammation releases cartilage-degrading enzymes into synovial fluid, thus resulting in cartilage damage (Scott et al, 2021; Guilak et al, 2004). The presence of synovial systems has a vital impact on the development of OA and the subsequent bone response visible on the skeleton (Sohn et al, 2012; Berenbaum, 2013).

However, osteoarthritis is only one type of arthritis, and ensuring that its differential diagnosis is correct is integral to its study. For example, rheumatoid arthritis (RA) is also one of the most common forms of arthritis though, unlike OA, it is not from the breaking down of cartilage within a joint. Instead, it results from an autoimmune response and a shared rheumatoid epitope (Gregerson, Silver & Winchester, 1987; Roberts-Thomson & Roberts-Thomson, 1999). Unlike OA, RA does not have evidence of bone remodelling around the site of the joint degeneration (Toivanen, 2001; Watt, 1997). This differentiation is observable upon a skeletal sample, and is an integral part of defining the presence of OA or RA. Like OA, many forms of arthritis are a secondary result of a wider relationship between health and individual predisposition (Roberts-Thomson & Roberts-Thomson, 1999). While research is still limited, in the context of Aboriginal Australians most forms of arthritis only appear in the pathological record at the point of colonisation (Roberts-Thomson & Roberts-Thomson, 1999). Neither RA nor ankylosing spondylitis are found on precolonial skeletons, likely due to the scarcity of predisposing genetic elements associated with these forms of arthritis (Roberts-Thomson & Roberts-Thomson, 1999). Osteoarthritis in Australia is the primary form of joint degeneration upon Aboriginal individuals, but it does not mean all degeneration found on Aboriginal skeletons is classified as osteoarthritis.

Other joint types, such as cartilaginous and fibrous joints, are defined differently under other terms encompassing joint damage (Ortner, 2003; Schrader, 2019). This means joints on the same bone, such as a vertebra, can have joint damage categorised under different terminology. For example, degeneration of the vertebra centrum is classed as degenerative joint disease or vertebral osteophytosis due to the absence of inflammation or synovial systems seen in osteoarthritis. This becomes an issue when those different joints are being studied under the same scoring method, in which presence, absence, and severity may all differ depending on scoring and definition. Although all joints can be affected by degeneration, not all joints can develop osteoarthritis.

4.2 Defining joint damage to non-synovial joints

Many terms have been used to describe degenerative joint damage, and often these terms have been used interchangeably. While these terms can change based upon minor differences in definition, a term most relevant to this thesis is Vertebral Osteophytosis (VO). VO is termed to describe osteophytes, which are ankylosing bony growths that develop on intervertebral margins (Maat et al, 1995). Instead of activity or motion, in the spine they are most commonly attributed to weight-bearing and pressure on the joints over one's lifespan (Maat et al, 1995). This is an important definition as this thesis will use two joint surfaces of the vertebrae to examine areas affected by activity, and joints such as the centrum are most affected by life-long pressure. Hence VO is most common in the lumbar vertebrae.

Determining how different terms are being used is integral to defining skeletal pathologies, as many of these terms overlap. However, they can be used in conjunction if their differences are addressed. This study will examine degeneration on the vertebral centrum alongside vertebral facet OA. Because the centrum is not a synovial joint, osteoarthritis cannot apply. The most predominant contributor to osteophyte development upon the centrum is thought to be age (Listi & Manhein, 2012; Prescher, 1998; Snodgrass, 2004). With age, the nucleus pulposus loses water content and turgor, causing decreased height of the intervertebral disc and less resilience to weight-bearing upon the joint (Klaassen et al, 2011). While such degeneration in the context of this study cannot be related to activity, it is important to understand the potential relationships of degeneration across the body, and how this may affect the presence or absence of OA.

Research has shown that the centrum is where spinal degeneration initially forms, and osteoarthritis on the facets follows (Fujiwara et al, 1999). Some even conclude that centrum degeneration is the primary cause of facet joint changes (Fujiwara et al, 1999; Vernon-Roberts & Pirie, 1977). However, this appears to best apply to the L1-S1 vertebrae (Fujiwara et al, 1999). Though facet OA has been observed to follow centrum development, there is still a relationship between age and facet OA (Gellhorn, Katz & Suri, 2013). It is important to analyse the aspects of the spine independently and then compare their relationship.

4.3 Osteoarthritis Aetiology

The aetiology of osteoarthritis is known to be multifactorial (Weiss & Jurmain, 2007; Waldron, 1997; Derevenski, 2000; Kahl & Smith, 2000; Lovell & Dublenko, 1999; Daste, 2021). What contributes to the development of OA on any one individual can vary on genetic contributions and lived experiences. OA is secondary to outside influence and develops in response to other factors. While anthropology focuses on the role of mechanical loading as a cause of OA, clinical literature encompasses other elements of OA formation (Weiss & Jurmain, 2007). This can include long-term labour or stress, injury, age, sex, genetic predispositions, and body-mass index (Gilmour et al, 2015; Weiss & Jurmain, 2007; Ganz, 2003). While each of these will be discussed, this complex aetiology has consequences for interpreting skeletal OA in the osteological record.

Models of aetiology show how different factors contribute to OA and what the origin of those factors may be. The model below (fig. 4.1) shows how OA develops from a combination of modifiable and non-modifiable risk factors, exacerbated by a predisposed or susceptible individual or joint. While predispositions and local risk factors described in figure 4.1 vary individually, these dispositions will change over one’s lifetime as they age, and the activities theycarry out change. The below figure clearly shows the relationship between factors and how variable this may be. While examining OA's aetiology and contributing factors, this chapter will focus on broader contributions, including age, body mass, and sex, in which micro-processes may contribute to OA. Yet, by focusing on these broader factors, a general sense of how OAdevelops can be understood, as fully explaining all factors contributing to OA pathology is beyond the subject or ability of this thesis.

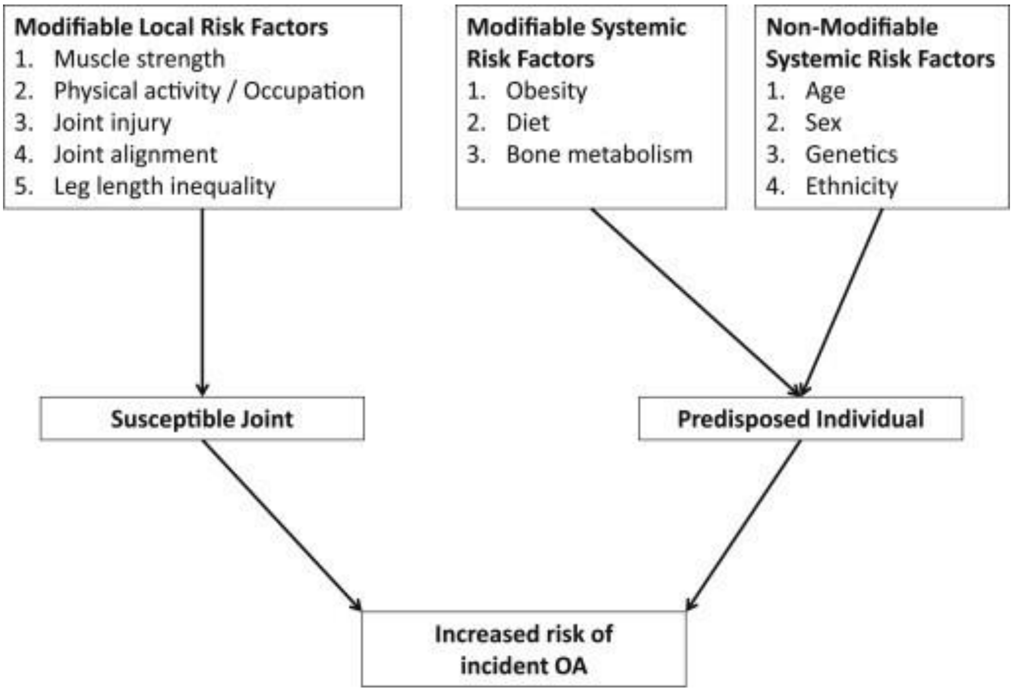

Figure 4.1 - Potential risk factors for susceptibility to OA incidence. From "The epidemiology of osteoarthritis." By Johnson, V. L, & Hunter, D. J. Best practice & research. Clinical rheumatology, 28(1), 5–15, 2014. https://doi.org/10.1016/j.berh.2014

4.3.1 Age

There is a positive correlation between age and OA (Waldron, 1994; Wiess & Jurmain, 2007), so much so that age is thought to be the most significant contributor. Age is the culmination of activity, genetics, body mass, and injury (Felson et al, 2000). Therefore, while age itself may be a secondary cause of OA, it reflects the life of an individual and how that life may influence bone degeneration (Lieverse et al, 2007). Such a statement implies that while age exacerbates the development of OA, something else lends itself to OA as a pathology. OA is not restricted to older individuals and has been observed on individuals of all ages. One study by Becker and Goldstein (2018) found children of a Tiwanaku colony to have a high frequency of

OA that was attributed to activity due to age being an unreasonable assumption. This is an uncommon occurrence made even more so by the adult-age focus of many OA studies (Schrader, 2019).

Although age is seen as a predominant characteristic of OA, its presence in older individuals cannot be written off simply as a consequence of age. Evidence of osteoarthritis in children is the effect of hard and rigorous activity from a very early age, and the consequences of such labour on nutrition and bone development (Becker & Goldstein, 2018). Old age as a factor in the presence of OA is a consequence of natural body degradation and lifelong cultural action.
OA will be accelerated in joints that have had the most stress put upon them, and age will only exacerbate this degeneration. Although it is a continuing issue of determining the impact of age in relation to other contributing factors of OA, joint damage and degeneration indicate lived experience and activity even in an aged population. This is especially so if this degeneration indicates social patterning.

4.3.2 Sex and Gender

Evidence has shown that osteoarthritis can vary based on sex. This is due to different hormones, body sizes, and anatomy of the different sexes, and the influence this can have on joint susceptibility and weight loading (Johnson & Hunter, 2014). Understanding the biological effect of OA and how it may manifest in different sexes is intrinsic to understanding how OA may manifest in a population. While skeletal populations tend to reflect higher OA rates in males, with today's ageing populations females are thought to be at a higher risk than males (Buckwalter & Lappin 2000; Busija et al. 2010). Hormone differences and body mass are thought to be the main contributors to sex differences in OA development. Lessened bone mineral density, bone strength, ligament laxity, pregnancy and neuromuscular strength are all thought to contribute to increased prevalence of OA in females (Johnson & Hunter, 2014; Nevitt et al, 2001).

Menopause is thought to be the main reason as to why females are more likely in their older age to develop OA when compared to males. This has been tied to hormonal changes as a result of menopause (Bellido et al, 2011; Gokhale, Frenkel & Dicesare, 2004). There is increasing evidence that oestrogen can contribute to the prevention of OA by homeostasis of articular tissues (Bellido et al, 2011; Xu et al, 2019). Subchondral bone loss has also been attributed to oestrogen loss, suggesting a different relationship between oestrogen and bone remodelling processes (Bellido et al, 2011; Xu et al, 2019). In Australia, the absence of older females in the skeletal record means that today's increasing OA may not be observable. However, age categories are broadly grouped, and individual variation in hormone changes mean that even in the individuals found at Roonka, the potential effect of hormone change on middle-aged and older females is something to consider.

By considering the effect sex may have on OA formation, OA as influenced by activity, injury or culture, can be critically analysed and understood separate from causes beyond personal or social control. Both social and biological factors influence how different groups develop and present markers of osteoarthritis. In a clinical sense, such differences can be discussed with the person who is part of the study. Anthropology must deconstruct this information from a broader context and understanding. The role of sex and what contributes to OA is vital in ensuring patterns observed result from daily life rather than the result of factors beyond personal control. However, it must also be understood that not everyone would have partaken in certain activities, nor would they have necessarily partaken in the same way (Becker, 2019a). Though sex may influence how OA may develop, labour and social influences mean that sex will not affect OA inthe same way across a population.

4.3.3 Body mass

Today the prevalence of osteoarthritis is increasing all around the world. In Australia, OA affected 2.2 million people in 2015, and that number is thought to only increase to 3.0 million people by 2032 (National Osteoarthritis Strategy Project Group [NOSPG], 2018). Clinically, this growing prevalence seen on weight-bearing joints, like the knee or hip, is thought to be attributed to growing rates of obesity (Anderson & Felson, 1988; King, March & Anandacoomarasamy, 2013; Schrader, 2019). Weiss (2005, 2006) conducted osteological studies that indicate little connection between body size and OA prevalence. With age and sex controls, hip osteoarthritis was negatively correlated with body mass (Weiss, 2006). While this study focused on osteological measures of body size and did not focus on body weight, they do show the complex relationship between size, weight, and OA.

When compared to other ethnicities, Aboriginal Australian crania are known to be very robust. However, the cranial robusticity does not carry down to the postcranial skeleton. There are ongoing debates about the variability and causes of Aboriginal cranial robusticity (Curnoe, 2009). The postcranial robusticity that is commonly thought for Aboriginal Australians is more likely large or heavily modelled muscle attachments, rather than the robusticity of bone itself (Pearson, 2000; Carlson, Grine & Pearson, 2007). The size of muscle attachments on the postcranial skeleton can indicate mobility or subsistence methods, especially if there is sexual dimorphism between such patterns that indicate differences in activity between sexes (Pearson, 2000). However, while indicative of activity, muscle attachment sites have little relationship with the development of osteoarthritis. While robusticity can be linked to OA, it would be difficult in the absence of postcranial robusticity.

While body mass and robusticity are not always linked, the increased pressure of mechanical forces found in more robust skeletons does show evidence of increased osteoarthritis (Brickley & Waldron, 1998). However, this evidence is sparse as there are very few skeletal samples from which a relationship between robusticity and OA can be adequately examined (Myszka, 2020). Modern samples in which robusticity and OA can be observed reflect patterns in which more robust bones are predisposed to OA (Brickley & Waldron, 1998). Though the relationship between body mass and OA is difficult to understand on a skeletal sample, this does not mean body mass or robusticity as potential causes or contributors can be ignored. Doing so would only limit potential analysis and interpretations of OA.

4.3.4 Injury

OA can be attributed as a secondary bone response to an injury or trauma. Today, sports injuries from overuse or trauma to a joint are the predominant way to understand how an injury or joint over usage can affect OA (Wade, 2011). Injury can directly damage joint tissues, and prevent the joint repair process from being carried out correctly (Litwic et al, 2013). Particular occupations or tasks may make particular joints more injury prone (Yucesoy et al, 2015; Anderson et al, 2012). Athletes or tradespeople are examples of people who are likely to develop OA secondary to injury (Gouttebarge et al, 2015; Schram et al, 2020). Direct tissue damage is not the only possible cause of OA from injury. The resulting biomechanical disruption and altered load distribution within the joint can also contribute to subsequent OA risk and development (Litwic et al, 2013).

While injury can be a significant contributor to OA development in a joint due to weakened and susceptible joint mechanisms, when examining OA in a population, individual injuries are unlikely to influence how OA is distributed. Patterns of injury across a population from which OA develops, can provide information regarding lived experience as to how such injuries occur and the possibility as to why (Gilmour et al, 2015; Novak and Šlaus, 2011. Joints that have been injured and subsequently developed OA must be carefully approached not to undermine the effect injury can have. This includes the question of whether a joint would be affected at all without such an injury. There is also the possibility that OA may have developed secondary to an injury, yet evidence of injury does not remain upon the skeleton. This possibility is likely in any sample and indicates a necessary awareness of the osteological paradox. The presence of injury must be carefully examined alongside the presence of OA in order to understand if OA was culturally driven, or a result of personal experience.

4.3.5 Activity

Until recently, labour was viewed as the primary cause of osteoarthritis, and OA was viewed as a ‘wear and tear’ disease (Jurmain, 1977; Schrader, 2019). Hand dominance, physically strenuous occupations, and occupations with specific repetitive movements have all been shown to increase the risk of osteoarthritis (Felson, 1994). For example, OA of the hand is associated with occupations with increased hand dexterity, such as textile workers (Felson, 1994; Hadler, 1977). Waldron's work (1991, 1997) on a Spitalfields skeletal collection is an extensive examination of the relationship between osteoarthritis and activity. This was enabled by comparing a modern group to the skeletal collection who were buried between 1729 and 1869 (Waldron, 1991). This was achieved by prior knowledge of age, sex, and occupation of many individuals whose remains were used. The work by Waldron further reiterated the difficulties of using OA and the interplay of activity, genetics, and wider social factors as contributors to its development (Waldron 1991, 1997). Osteoarthritis is better examined in living people. Thus, clinical examinations of OA are more in-depth in their pathogenesis. When analysing OA in a skeletal population, there are only limited ways in which it can appear on bone.

Clinical literature describes activity as being only one contributing factor to the development of osteoarthritis. OA is generally defined in the clinical sense through radiology as a combination of joint pain and diminished joint space (Vignon et al, 2006; Johnson & Hunter, 2014; Kraus et al, 2017). Clinical diagnosis of OA represents the early inflammatory stages of development, which in an osteological sense, is not visible upon a skeleton (Waldron, 2019). The harm of activity to joints remains challenging to define with any precision, yet joint function is understood in two forces: load transfer and movement (Vignon et al, 2006). The interplay between these forces increases the susceptibility of a joint to OA.

Regarding activity, early clinical studies viewed OA as caused mainly by repetitive movement on the joint that causes excessive load (Johnson & Hunter, 2014). It was then theorised that OA could be used to reconstruct lifestyle and life events (Wiess & Jurmain, 2007; Cheverko & Bartelink, 2017; Austin, 2017; Bridges, 1991). While this analysis has fallen short when attempts to name specific activities were made, general patterns and trends of OA, placed within a cultural context, are increasingly informative. Although activity and OA have long been intertwined, as more understanding is gained about this relationship, activity as a contributing factor to OA can be properly analysed and estimated (Wallace et al, 2022; Jurmain et al, 2012). This includes examining patterns attributed to activity through social or biological roles. Though issues regarding the interpretation of OA are becoming better recognised, it currently remains a problematic area to interpret.

The most well-known, early example of using osteoarthritis as a possible marker of activity began with Angel's (1966) examination of Native American remains from Tranquility, California, in which he used osteoarthritis to review past lifeways. Osteoarthritic changes observed in the elbow were concluded as being indicative of spear throwing. Wells (1962, 1972) and Ortner (1968) similarly produced work that sparked interest in the possibility of osteoarthritis as indicative of lifeways. Analysing osteoarthritis has often been done by assessing markers and examining which joints are most affected, the severity of OA markers, and variation across different groups of the sample. From this, the possibility of using osteoarthritis to examine economy or subsistence methods has arisen, alongside the opportunity of examining differences in activity patterns across the sexes (Lovell & Dublenko, 1999; Cohen & Armelagos, 1984; Ortner, 1968).

Not only do the clinical and paleopathological definitions differ, but determining how osteoarthritis can be best recognised on the skeleton has been debated (Waldron, 2019). This lies in determining whether joint damage is caused by osteoarthritis, or if another pathology with similar traits caused the degeneration. OA in paleopathology can be quite recognisable in later stages due to the presence of osteophytes and eburnation (Sandison, 1968; Molnar; Ahlstrom & Leden, 2011; Rogers & Waldron, 1995). Pitting, osteophytes and joint remodelling have been attributed to the skeletal presence of OA (Rogers & Waldron, 1995). The methods of addressing OA in past populations are limited by the skeletal response to inflammation and soft tissue degradation. Not only are we missing the extent of OA due to soft tissues of the joint very rarely surviving today, but how we can interpret OA depends upon whose osteoarthritis developed past the soft tissue. Precolonial Aboriginal Australians had extremely low rates of OA present on the skeleton. While this is not representative of the number of people who would have had OA based upon inflammation of the soft tissues, understanding how OA develops within a certain group of people is vital to examining how it could be used as an indication of activity.

4.4 Osteoarthritis and Aboriginal Australia

Today, Aboriginal Australians have some of the highest osteoarthritis and degenerative joint disease rates across the Australian population. This rate is thought to be a combination of socio-economic factors, including general health, nutrition, access to healthcare, and more (Australian Institute of Health and Welfare [AIHW], 2020; NOSPG, 2018). In 2004-5, after controlling age and sex, Aboriginal Australians and Torres Strait Islanders were 1.2 times more likely to develop OA than non-Aboriginal individuals (Australian Bureau of Statistics, 2011; McDougall, Hurd & Barnabe, 2017). The percentage of Aboriginal Australians with signs of OA is not a unique phenomenon, as many indigenous communities worldwide have reported high numbers of people affected by OA or other chronic conditions than non-indigenous individuals (O'Brien et al, 2020). In Australia, 90% of indigenous adults over the age of 35 have at least one chronic health condition, including diabetes, obesity, cardiovascular disease and respiratory illnesses (Australian Bureau of Statistics, 2016; O'Brien et al, 2020). Paired with the risk of chronic disease and the systemic impacts of healthcare, osteoarthritis is only one of many chronic issues that affect the health of Aboriginal Australians today. While variable across the country, osteoarthritis in precolonial Australia shows the greatest prevalence in the Murray region, in which Roonka is located (Webb, 1984). Paleopathological surveys have noted that the elbow, wrist, and temporomandibular joint are the most common areas for OA, with patterns of such varying upon age, sex and geographic location (Webb, 1984; Jurisich and Davies, 1976). It is important to note that Webb (1984) observed similar patterns ofelbow osteoarthritis between males and females, and bimanual loading was common in both sex categories along the Murray. Hill (2019; 2020) furthers this by highlighting bimanual loading at Roonka, the patterns of which changed over the Holocene. Although the exact causes of increased osteoarthritis in this region are unknown, it is important to note. It is part of the reason as to why Roonka provides the opportunity for this study.

Although particular patterns of OA have been attributed to particular activities, it is unlikely that OA is dependent on type of subsistence economy (Bridge, 1992). Areas of the body where OA is most likely to develop, including the elbows, wrists, and knees, are common across all types of subsistence economies. These joints tend to be most affected due to continual use or prolonged pressure upon joints. However, hunter-gatherer societies show substantially less OA than sedentary or agriculturalist societies (Inoue et al, 2001; Wallace et al, 2017; Webb, 1995). It has recently been theorised that activity inhibits the development of osteoarthritis, which is why hunter-gatherer societies have less OA than less active societies (such as post-industrial) (Wallace et al, 2022). This, however, will still be tied to the genetic predisposition to OA, alongside the cultural context of activity type and the age at which these activities would be carried out. In Aboriginal Australians, the low frequency of OA across the continent, and the absence of other types of arthritis prior to colonisation, suggest that genetic predispositions are low (Webb, 1984; Roberts-Thomson & Roberts-Thomson, 1999).

While wider factors, such as age, sex, and body mass, will all influence how OA may present across different groups, culture will play a part in how the body responds to pressures put upon it, including the pressures that will exacerbate joint degeneration. Separating the culture from the biological causes is almost impossible. Yet, it is consistent that OA will likely always develop within a population in some form. While issues in its use are becoming strikingly obvious, in a population with a small amount of bone pathology or trauma, it provides an ample starting point.

4.5 Flaws of using osteoarthritis

The flaw of studying OA and applying it to activity is that, as displayed above, it has a complicated and intertwined aetiology with which careful consideration is key. The interplay between the social and biological contributions to OA make interpretations of lived experience difficult, as it can be easy to find patterns where there are none. On an individual basis, it is extremely difficult to determine the root causes behind its formation (Domett et al, 2017). The pitfalls of many OA studies are that the relation between activity and OA has often been simplified into a cause-and-effect relationship, with the complexity of such relationships often going unacknowledged (Jurmain et al, 2012). No single reason listed throughout this chapter, nor any that went unmentioned, are all-encompassing causes of OA.

The factors behind OA cause be broadly categorised into (1) exposing the joint to risk (local risk factors), or (2) exposing the individual to risk (systemic risk factors) (Shrader, 2019). The relationship between genetic joint susceptibility and systemic risk factors determines how and to what degree OA may develop on a joint. What this makes difficult is how one could separate different contributing factors of OA to determine how likely a particular cause may be. Osteological study of OA exacerbates this, as bone is the only evidence available for OA analysis. Areas where OA may have only been beginning to develop in soft tissues are unknown to us, so while OA is one of the most common forms of skeletal pathology, the true extent of its presence cannot be known in a skeletal sample.

4.6 Osteoarthritis in this study

In this thesis, activity is being used as a proxy to understand gender and the potential social organisation gender may encompass. While osteoarthritis as a marker of activity has several flaws regarding interpretation and application, it is still helpful as an indication of lifeways and population-wide patterns of activity. These are patterns that are unlikely to develop solely based upon variables such as body mass, genetics, or injury, which can vary significantly from person to person. Such patterns can be extremely useful in not only contributing to our understanding of how OA may develop in particular populations, but can also contribute to understanding what potential causes behind such patterns may be. However, in order to best avoid the pitfalls of OA as a method, focus must primarily remain on the group rather than the individual. Although individual variation in OA development can be insightful, the whole sample must beconsidered first to know when OA develops and how across the sexes. These broader differences are most indicative of socially driven activity, and within these patterns are the individuals who stand out amongst their group.

Gender in Aboriginal populations in a paleopathological context has been understudied and often been approached from a western perspective of what gender means. Although osteoarthritis is a general approach to activity and requires acknowledgement of broader contributing factors, it can possibly allow for a general understanding of gender in a way that encompasses population-level patterns of pathology. Sex is known to be a social organiser in Aboriginal societies and using OA to examine the differences seen in the sexes will allow gender to be inferred. OA can occur in anybody, and though its presence may differ between the sexes, its development is almost assured regardless of sex. Its ubiquity amongst the sexes means that gender can be detected, provided the sample is large enough.

Chapter Five: Methods and Materials

5.1 Materials

The sample is comprised of skeletons found at Roonka, South Australia by Graeme Pretty from 1968-1977 (Pretty, 1977). Acknowledged to be the ancestors of the River Peoples of Murray and Mallee Association Inc, these individuals represent a span from the early Holocene to the early colonial period (7000 BP – 150 BP) (Littleton et al, 2017a). A minimum of 216 individuals have been excavated from the site. Individuals included in this study represent a sub-set of 90 excavated individuals who were identified as adult and had at least one joint surface that could be assessed for the presence of OA.

5.1.2 Aging and sexing

The individuals were aged into categories determined by Littleton et al. (2017a). These categories were grouped using ageing criteria described by Buikstra and Ubelaker (1994). Ageing was done by Littleton and postgraduate students in 2013. The pelvic elements of the auricular surface of the innominate, and the pubic symphysis were primarily used as they undergo adult age-related changes (Brooks & Suchey, 1990). Cranial markers of fusion and obliteration of sutures were used secondarily. Minimum developmental age for inclusion was based upon complete eruption of all permanent dentition (McKenna et al, 2002; Brown, 1969; Massler et al, 1941). Age categories used were Young Adult (20-35), Middle Adult (36-50), Old Adult (51+), and Unknown age.

Sexing was done using features of the skull and pelvis as recommended by Littleton and Kinaston (2008). Although the whole skeleton was viewed when sexing, emphasis was placed on pelvic indicators of sex. The subpubic region and greater sciatic notch were the focus of pelvic sex analysis. Secondary to pelvic indicators was the crania. The nuchal crest, the supraorbital margin and ridge, mastoid process, and mental eminence were the focus of cranial analysis.

Due to the robusticity of Indigenous Australian crania, standardised non-metric sex assessments, such as Buikstra and Ubelaker (1994), may reduce the accuracy of sex estimation, underestimating numbers of females in Australian samples. This is relevant for populations contributing to Roonka as Brown (1981) found that the robusticity of crania, especially along the Murray River, confused attempts to categorise sex. Brown found an overlap in cranial measurement ranges affected the reliability of sex estimation. This could be overcome by limiting non-metric traits towards a limited scale of robust features (Brown, 1981). Brown's (1981) approach was used by Littleton when remains from Roonka were reanalysed (Littleton et al, 2013).

The sex categories used are Female, Probable Female, Indeterminate, Probable Male, and Male. In order to assess whether these categories could be appropriately further consolidated, I compared numbers of individuals, and then joint surfaces, for OA presence versus absence. This was done in two pairs of categories: probable males vs. males or probable females vs. females. If judging from Fisher's exact tests and associated odds ratios, these pairs did not differ significantly ($p > 0.10$) then these groups were consolidated as male or female. In this case they will become Female, Male, and Indeterminate.

5.2 Methods

The aim of this analysis is to understand if differences in patterns of activity, inferred from distributions of OA and VO, provide information about Aboriginal gender and gender roles associated with peoples interred at Roonka. While use of presence or severity of OA and VO are not direct indicators of specific activities, patterns of OA or VO may provide a general understanding of possible activity patterns, from which gender can be parsed, and in the future can hopefully be more deeply analysed and examined.

5.2.1 Recording of OA and VO

In order to analyse potential skeletal markers of activity, postcranial osteoarthritis and vertebral osteophytosis (VO) of the centra are being examined. While similar, OA and VO are defined differently. Therefore, when examining vertebral joint degeneration, both will be used in order to differentiate these kinds of degeneration.

5.2.1.1 Non-vertebral Skeletal Remain

The osteoarthritis data used is pre-existing pathology data recorded from the Roonka Skeletal collection. Records of pathology were done in 2018 by Judith Littleton and Sarah Karstens. Done to the standards of Buikstra and Ubelaker (1994), each joint was given a score of 0 to 4, depending on the observable trait (Table 5.1). Joints unobservable were left blank on the recording sheets. This score is based on the appearance and degree of bone formation or deformation, located on the surface of the whole joint. Postcranial joints were given a general score (of 0-4) that encompassed the whole joint surface.

Table 5.1 - Scoring of osteoarthritis based upon standard by Buikstra & Ubelaker (1994, table 8.0.0).

Score	*Definition*
Score 0	Nothing – no observable signs of joint degeneration.
Score 1	Small deposits on articular surface, barely discernible.
Score 2	Pitting or spicules on joint surface.
Score 3	Polishing/Eburnation
Score 4	Ankylosis of the joint.

In order to include all joint surfaces within analysis, this thesis will consolidate joint surfaces into joint regions (Zhang et al, 2017; Larsen & Kelly, 1995; Molar, 2011) (Table 5.2). This is done because of the potentially large number of data points per joint. For example, four joint surfaces of the knee, multiplied by two scores per surface means eight potential data points per individual in the knee alone. Although specific joint surfaces will be examined if they are relevant, by focusing on broader joint areas affected joints are better contextualised in the framework of activity, and joint areas that are of relevance can be better addressed and focused upon.

Table 5.2 - Joint areas and associated joint surfaces.

Joint Area Name	*Joint surfaces*
Crania	Occipital, Temporomandibular (TMJ) & Mandibular Condyle
Shoulder Girdle	Sternoclavicular, Acromioclavicular, Glenoid, Humeral Head
Elbow	Capitulum, Trochlea, Radial Head, Proximal Ulna
Wrist	Distal Radius, Distal Ulna
Hand	Metacarpals, Phalanges (Hand), Carpals
Hip	Sacroiliac, Acetabulum, Femoral Head
Knee	Femoral Condyle, Patella, Proximal tibia
Ankle	Distal Tibia, Distal Fibula, Calcaneus, Talus
Foot	Tarsals, Phalanges (foot), Metatarsals

5.2.1.2 Vertebral degeneration

The vertebrae were divided into the centra and the facets. The facets, which can be affected by osteoarthritis, were given a score of 0-4 following the same standards of Buikstra and Ubelaker (1994) noted above. Each centrum was given a similar score of 0-4, representing the presence and extent of vertebral osteophytosis (Table 5.3).

Table 5.3 - Osteophytosis scoring based upon standards by Buikstra and Ubelaker (1994, table 7.0.0).

Score	*Definition*
Score 0	Absent – no observable signs of osteophyte development.
Score 1	Barely discernible.
Score 2	Elevated ring of bone.
Score 3	Curved Spicules or well-formed bony spurs
Score 4	Fusion or ankylosis present.

The vertebral scores were divided by the porosity, facets, and centrum. Each were given an independent score for each vertebra. Porosity in this sample was scored as present or absent on each vertebral centrum. While vertebral porosity does have some relationship with vertebral loading, the potential relationship between activity and vertebral porosity is not well understood (Bonnheim et al, 2021). Evidence has shown that porosity is likely a secondary effect of OA, rather than primary (Woods, 1995; Domett et al, 2017); likely a result of the increased vascular activity aiding maintenance of cartilage tissue (Rothschild, 1997; Woods, 1995). It can occur without the manifestation of OA, and therefore cannot be directly linked to the presence of OA (Ortner, 1968; Rothschild, 1997). While there is some form of relationship between porosity and osteoarthritis, this relationship is not yet well understood. While it will be recognised and examined to some degree here, it will not directly relate to scores of osteoarthritis or vertebral osteophytosis.

Degeneration of the vertebrae is closely associated with age (Burt et al, 2013; Waldron, 2009). While the relationship between activity and degeneration of the vertebrae is complicated and not entirely understood (Myszka, Weiss & Piontek, 2014), there is a difference in overall prevalence of vertebral degeneration across different communities, suggesting that labour may have some influence over spinal degeneration (Bridges, 1992; 1994). The vertebral centra, as a cartilaginous joint, will be scored using osteophytosis scoring (See table 5.3 above). The vertebral facets, as a synovial joint, will be scored based on osteoarthritis scoring (See table 5.2 above). The two joint types both play different roles within the spine, so they are both being analysed. Both the vertebral centra and facets will be split by vertebral region, similarly to the non-vertebral body. These regions will be the Cervical (C1 - C7), Upper thoracic (T1 - T6), Lower thoracic (T7 - T12), Lumbar (L1 - L5), and Sacrum (S1).

All joints were given individual scores for left and right when present. The left and right of each joint will be examined in the non-vertebral body. The vertebrae, both facets and the centrum, will only be considered as a whole. Vertebral analysis and postcranial skeleton analysis will be carried out separately. Patterns of interest within the two will be compared and discussed in relation to one another.

5.2.2 Statistical analyses

This analysis aims to understand if gender, and potential gender roles, can be made visible through patterns of activity, as understood through osteoarthritis. Every individual has a skeletal I.D number, age category, and sex category. This will allow analysis of each joint to be undertaken by each of the aforementioned categories as needed. Osteoarthritis will be analysed first and foremost by sex categories, and then further analysed based on age. This will be doneto first find evidence of possible gender through differences in sex. As Roonka has age stratified activity patterns (as seen through dental wear) (Littleton, 2017a), differences in OA across age categories will then be examined.

Statistical analysis is carried out through RStudio. Postcranial OA, OA of the vertebral facets, and VO of the vertebral centra were all analysed independently, and then compared to examine how OA is distributed across the body, and if this distribution could correlate to differential daily activity. This data will require analysis using multiple tests. This is due to both the nature of the data, and the way the data is organised. The main variables are sex: a nominal variable, age: ordinal and degeneration severity: ordinal on a scale of 0 to 4.

This study will also rely upon odds ratio analysis, carried out in RStudio using the "Stats" and "Rstatix" R packages. Odds ratio will allow for an estimate of the relationship between two binary variables, and this relationship can be easily examined in the context of different variables. (Bland & Altman, 2000). For ease of interpretation, all odds ratio tests will compare the likelihood of males to females unless specifically outlined or discussed. It can be interpreted that the odds ratio value represents an increased likelihood in the male group than female. This was chosen based on other analyses which indicate Australian males have higher frequencies of OA (Webb, 1984).

Chapter Six: Results

This chapter will focus upon skeletal differences in joint degeneration. First, an intra-observer error study to done to assess how available data consistently was used. The assessments of reliability will contribute to two questions. First, was use of the data set consistent so that statistical analyses and associated interpretations may be judged reliable? Second, is there a difference in how reliably male and females were counted and assessed within a given joint?

6.1 Intra-observer error

6.1.1 Observations of individual record of degeneration

In order to assess the intraobserver error for individual records of OA, ten individuals were randomly selected, and their original pathological record was compared to the entered data that underwent analysis. Because this study used pre-assessed and scored OA, reassessing individuals' joint surfaces or individuals using the skeletal remains could not be done. The reassessment of OA records were in complete agreement with the original recording of OA. This was likely due to clear original records of pathology for each individual, and clear communication with the original recorders of the pathology of this sample.

6.1.2 Observations of the presence of Osteoarthritis in the TMJ

A joint surface, the TMJ, was randomly chosen to be re-counted. The number of observed and affected joints was re-assessed and the new counts compared to the original number of observed and affected joints. This difference was examined for each sex category. Table 6.1 shows that there was no difference in the recount of the observed and affected individuals for any sex category.

Table 6.1 - Original and recounted frequency of affected and non-affected TMJ of individuals.

	Female	*Probable Female*	*Indeterminate*	*Probable Male*	*Male*
Original Count	6/10	3/6	0	1/6	4/15
Re-count	6/10	3/6	0	1/6	4/15

This recount was also carried out for affected joint surfaces within the TMJ and again compared across sex categories (Table 6.2). While the recount remains largely the same, there was one error in counting males who had observable joint surfaces. A further check indicated that the recount score (28) was correct, not the original of 27.

Table 6.2 - Original and recounted frequency of affected and non-affected joint surfaces in the TMJ.

	Female	*Probable Female*	*Indeterminate*	*Probable Male*	*Male*
Original Count	6/17	4/10	0	1/10	6/27
Re-count	6/17	4/10	0	1/10	6/28

6.2 Preliminary Assessment and Consolidation of Sex-Associated Categories

Table 6.3 shows the numbers of individuals and joint surfaces where OA is present or absent in the five original sex-associated categories. Fisher's exact tests indicate that the comparison of odds ratios for male versus probable male ($p = 0.21$; 95% CI: 0.84 – 2.29), or female versus probable female ($p = 0.85$; 95% CI: 0.52 – 2.71) were statistically significant ($p \leq 0.10$). Because of this, they were consolidated as male and female, respectively, for the remaining analyses.

Table 6.3 - Number of individuals and joint surfaces with and without observed OA by sex-associated categories.

	Male	*Probable Male*	*Indeterminate*	*Probable Female*	*Female*	***Totals***
Individual						
OA Present (n)	14	9	1	6	13	**43**
OA Absent (n)	7	11	7	10	9	**44**
Joint Surface						
OA Present (n)	66	27	1	11	20	**105**
OA Absent (n)	467	262	105	300	471	**1605**

6.3 Non-vertebral Osteoarthritis

Of the 90 total individuals who make up the sample, 87 individuals (97%, 87/90) have observed joint surfaces across the non-vertebral skeleton. There is little difference between the consolidated sex categories of these observed individuals. Female individuals make up 44% (38/87) of observed individuals, and males make up 47% (41/87) of observed individuals. There are eight individuals (9%, 8/87) of indeterminate sex. These eight individuals will be excluded from future analyses that evaluate differences by sex. Observed male and female joints combined make up 1,624 joint surfaces. Of this, 49.4% (802/1,624) are female joints surfaces and 50.6% (822/1,624) are male.

Table 6.4 shows the count of affected and unaffected individuals and joints across sex categories. The differences between affected male and female individuals shows that while males have a slightly higher likelihood to be affected with OA, the differences in affected individuals are insignificant (OR= 1.27, p=0.66). Count of affected joints, however, do show a statistically significant difference between the sexes. Male joints are 3.17 times more likely to be affected with OA than females ($p \leq 0.0005$).

Table 6.4 - Presence and absence of OA based upon count of joints and individuals by sex.

	Female		*Male*	
	Joint	Individual	Joint	Individual
Presence (Score 1-4)	31/802	19/38	93/822	23/41
%	3.9%	50.0%	11.3%	56.1%
Absent (Score 0	771/802	19/38	729/822	18/41
%	96.1%	50.0%	88.7%	43.9%
Total	802	38	822	41

The differences between affected male and female individuals shows that while males have a slightly higher likelihood to be affected with OA, the differences in affected individuals are insignificant (OR= 1.27, p=0.66). Count of affected joints, however, do conclude a statistical difference between the sexes than indicate male joints are 3.17 times more likely to be affected with OA than females (p=<0.0005).

Table 6.5 shows how severity scores vary across the sex categories. This sample does not have any joints scored 4, so further references to affected joints scores will only mention 1 through 3. There are only two joint surfaces affected with score 3, and both joints are found in the male group. Consistent with this, males also have a higher proportion of affected joints with OA scores of 1 or 2. Female joints make up a higher proportion of joints that do not have OA present, though the difference is relatively small.

Table 6.5 - Counts and percentages of affect joints by score (1-4) and sex.

	Score 0	*Score 1*	*Score 2*	*Score 3*	*Score 4*
Female	771	11	20	0	0
%	96.1%	1.47%	2.5%	0.0%	0.0%
Male	729	50	41	2	0
%	88.7%	6.1%	5.0%	0.2%	0.0%
Total	**1500**	**61**	**61**	**2**	**0**
Total %	**92.4%**	**3.8%**	**3.8%**	**0.1%**	**0.0%**

A chi-square test was carried out to assess the relationship between OA severity and sex using rows of score 0, score 1, and score 2 or more. These results indicate a significant relationship between sex and OA score (χ^2 =3.26, df=2, p=<0.0005).

6.3.1 Age and sex in the non-vertebral skeleton

Because of the positive relationship anticipated between age and the risk of OA, how age may impact the presence of OA on the non-vertebral skeleton is an important consideration when attempting to examine differences in activity. There are a further 12 individuals of indeterminate age who were excluded from this analysis.

Table 6.6 shows how observed OA varies across the age categories of this sample. There is no observable difference between the affected and non-affected individuals by age. While the young adult category does have a relatively high percentage of affected individuals, all but one (female) young adult has only one joint surface affected. The middle adult group has a difference of three affected individuals between the two sex categories. However, this difference is not statistically significant (OR= 2.52, p=0.43). There is no sex-associated difference in the affected individuals in the old adult category.

Table 6.6 - Frequency of affected joints and individuals by age group and sex.

	Young Adult		*Middle Adult*		*Old Adult*	
	Joint	Individual	Joint	Individual	Joint	Individual
Female	5/255	4/13	16/428	10/16	10/101	5/8
%	2.0%	30.8%	3.7%	62.5%	9.9%	62.5%
Male	5/227	3/11	44/422	13/16	33/125	5/8
%	2.2%	27.3%	10.4%	81.3%	26.4%	62.5%
Total	**10/482**	**7/24**	**60/850**	**23/32**	**43/226**	**10/16**
%	**2.1%**	**29.2%**	**7.1%**	**71.9%**	**19.0%**	**62.5%**

There is a statistically significant difference in the frequency of affected joints in the middle and old adult categories. In the middle adult age group, male joints are 2.99 times more likely to be affected with OA than female joints (p=0.0001). Given the similarly in the number of affected individuals, this also means that males have more OA per individual than females in the middle adult group. Old adult male joints also have an increased likelihood of being affected with OA than female joints (OR=3.25, p=0.001). However, one old adult male (Individual 584) has 20 affected joints, making up 60.6% (20/33) of all old adult male joints scored 1-3. If this individual is removed from the old adult male group (new count 13/92), the difference in affected joints by sex is no longer statistically significant (OR= 1.49, p=0.38).

6.3.2 *What areas of the non-vertebral skeleton are more frequently affected?*

Joints were analysed by skeletal region in order to understand where the differences in the sexes lay across the skeleton. Table F shows that most affected individuals primarily have OA on the upper body, with the lower body (Hip to foot) having the lowest percentages of affected individuals. The most affected joint areas by individual count are the crania, shoulder girdle, elbow, and the wrist. Females only have a higher proportion of affected individuals in the crania, with 57.9% (11/24) of total affected females having cranial OA. In the shoulder, elbow and wrist, males have a higher percentage of affected individuals than females. Of these joints the wrist has the highest frequency of affected males. Also of interest are the knee, ankle, and foot. These joints have low overall frequency of affected individuals, yet out of 11 individuals with OA in these joints, only one is female.

Table 6.7 - Affected (Score 1-3) and non-affected individuals by sex and joint area.

	Female		*Male*		***Total***	
	Individual	%	Individual	%	**Total**	**%**
Crania	11/24	45.8%	6/25	24.0%	**17/49**	**34.7%**
Shoulder Girdle	2/26	7.7%	9/28	32.1%	**11/54**	**20.4%**
Elbow	4/31	12.9%	8/26	30.8%	**12/57**	**21.1%**
Wrist	4/19	21.1%	9/19	47.4%	**13/38**	**34.2%**
Hand	1/27	3.7%	1/23	4.3%	**2/50**	**4.0%**
Hip	2/28	7.1%	3/27	11.1%	**5/55**	**9.1%**
Knee	1/25	4.0%	5/26	19.2%	**6/51**	**11.8%**
Ankle	0/18	0.0%	2/18	11.1%	**2/36**	**5.6%**
Foot	0/29	0.0%	3/20	15.0%	**3/49**	**6.1%**

Table 6.8 reports odds ratios and the results of Fisher's exact tests examining the presence of OA within joint area by sex. Because of the absence of affected females in the ankle and foot, odds ratios could not be computed. Only the shoulder girdle has a statistically significant difference in the count of affected individuals in the sex categories. While males have increased likelihood to be affected by OA in all joint areas by the crania, affected males are 5.81 times more likely than females to have OA in the shoulder girdle.

Table 6.8 - Odds ratio analysis of affected individual by sex and joint area. Significant scores are highlighted yellow.

	Crania	*Shoulder Girdle*	*Elbow*	*Wrist*	*Hand*	*Hip*	*Knee*	*Ankle*	*Foot*
Odds Ratio	0.28	5.81	2.94	3.26	1.18	1.61	5.54	N/A	N/A
P-Value	0.14	0.04	0.12	0.17	1	0.67	0.19	N/A	N/A

Table 6.8 shows frequencies of affected joints by joint area and sex. The crania, elbow, and wrist show the highest proportion of affected joint surfaces. Most affected joints of the crania can be attributed to the temporomandibular joint (TMJ) and the mandibular condyle which makes up 96% (24/25) of joints affected with OA in the crania. Because of this the TMJ and mandibular condyle will be grouped into just the TMJ, and it will become the focus of future analysis. The TMJ is the only joint with a higher frequency of affected female joints than males. Males have a much higher frequency of OA in the shoulder, elbow, and wrist. As this

corresponds with the count of affected individuals this frequency can be expected. The overall low frequency of OA in the lower body, yet the higher proportion of affected joints in the male group is also of interest. Given the high-mobile nature of hunter-gatherer societies that causes strain upon the lower limbs, this difference is unexpected.

Table 6.9 - Affected and non-affected joint count by joint area and sex.

	Female		*Male*		***Total***	
	Joint	%	Joint	%	**Total**	**%**
Crania	13/64	20.3%	12/75	16.2%	**25/139**	**18.0%**
Shoulder Girdle	5/77	6.5%	11/87	12.6%	**16/164**	**9.8%**
Elbow	4/130	3.1%	23/127	18.1%	**27/257**	**10.5%**
Wrist	4/46	8.7%	14/51	27.5%	**18/97**	**18.6%**
Hand	1/92	1.1%	1/80	1.3%	**2/172**	**1.2%**
Hip	3/93	3.2%	6/119	5.0%	**9/212**	**4.2%**
Knee	1/90	1.1%	9/143	6.3%	**10/233**	**4.3%**
Ankle	0/47	0.0%	2/48	4.2%	**2/95**	**2.1%**
Foot	0/146	0.0%	6/117	5.1%	**6/263**	**2.3%**

Table 6.10 shows what joint areas have a significant difference in affected joints across the sexes. Only the elbow and the wrist have a statistically significant difference in the chance of affected joints. The elbow and wrist are the only joint areas with a statistically significant difference between the sexes, contrasting the insignificant differences observed in the count of affected individuals.

Table 6.10 - Odds ratio analysis of affected joint count by sex and joint area. Significant scores highlighted yellow.

	TMJ	*Shoulder Girdle*	*Elbow*	*Wrist*	*Hand*	*Hip*	*Knee*	*Ankle*	*Foot*
Odds Ratio	0.19	2.1	6.92	3.92	1.15	1.55	5.94	N/A	N/A
P-Value	0.82	0.2	<0.0005	0.02	1	0.73	0.09	N/A	N/A

Most OA of the shoulder is found in the acromioclavicular and sternoclavicular joints which make up the majority of shoulder OA (68.8% 11/16) rather than the glenoid or humeral head. In comparing shoulder OA across the sexes, while there was no statistically significant difference, it was swayed by one individual. Four of the five affected joints in the female group are from one individual (Individual 576). If their joints were removed from the joint count of the shoulder, the difference in affected joints becomes significant (OR=9.87, p=0.01). This individual is also of interest as the only female in the sample to have OA in the sternoclavicular and acromioclavicular joints (both in the shoulder girdle), of which 63.4% (7/11) affected joints are found in the male group.

6.2.3 *Age and Joint area.*

Table 6.11 shows the difference in count of affected joints by age and sex category. The old adult age group has the highest percentage of affected joints in both sex categories, followed by the middle adult group. Only the elbow, wrist and TMJ show OA development from a younger age , while all other joints show OA from the middle adult age category. Females only have an increased proportion of affected individuals in the middle adult TMJ, whereas males have a higher proportion of affected joints in all other joint areas and in all three age categories. It is also of note that lower body OA appears in the middle adult male group and continues to havelow frequency in the female group.

Table 6.11 - Affected and non-affected joint areas by age and sex category.

	Young adult				*Middle adult*				*Old adult*			
	F	%	M	%	F	%	M	%	F	%	M	%
TMJ	3/16	18.8%	3/15	20.0%	7/30	23.3%	3/34	8.8%	3/10	30.0%	5/15	33.3%
Shoulder G.	0/29	0.0%	0/20	0.0%	5/42	11.9%	6/49	12.2%	0/6	0.0%	5/18	27.8%
Elbow	2/45	4.4%	1/33	3.0%	2/63	3.2%	14/75	18.7%	0/22	0.0%	8/19	42.1%
Wrist	0/12	0.0%	1/13	7.7%	1/29	3.4%	8/29	27.6%	3/5	60.0%	5/9	55.6%
Hand	0/24	0.0%	0/29	0.0%	0/54	0.0%	1/39	2.6%	1/15	6.7%	0/12	0.0%
Hip	0/30	0.0%	0/38	0.0%	1/53	1.9%	3/43	7.0%	2/12	16.7%	0/11	0.0%
Knee	0/23	0.0%	0/34	0.0%	0/56	0.0%	5/55	9.1%	1/12	8.3%	5/17	29/4%
Ankle	0/17	0.0%	0/12	0.0%	0/25	0.0%	1/26	3.8%	0/6	0.0%	1/9	11.1%
Foot	0/55	0.0%	0/31	0.0%	0/73	0.0%	2/65	3.1%	0/19	0.0%	4/21	19.0%
Total	**5/251**	**2.0%**	**5/225**	**2.2%**	**16/425**	**3.8%**	**43/415**	**10.4%**	**10/107**	**9.3%**	**33/131**	**25.2%**

While females have higher frequency of affected joints in the middle adult TMJ than males, this difference is not statistically significant (OR= 2.99, p=0.17). All other female joints are at a lower frequency than male joint count.

Males in the middle adult elbow were 31 times more likely to have affected joints in the elbow than females (OR= 31.75, p= <0.0005). However, while females have no affected joints in the old adult elbow, all eight affected male elbow joints are from one individual. The frequency of affected joints in the wrist is also statistically significant in the middle adult male and female groups (OR= 10.29, p=0.02), however, this difference disappears in the old adult group (OR=0.84, p=1). The shoulder girdle, bearing in mind four of the five affected middle adult female joints are from one individual, does not show a statistical difference between the sexes (OR=1.03, p=1).

7.2.4 Sidedness of Joint OA

Figure 6.1 shows the extent that the frequency of observed joints with OA vary by side in the males and female skeletons. Apart from the TMJ, there is relatively little difference in the expression of OA by side among the people buried at Roonka Flat. While the greatest difference in OA frequency between sides for a joint area occurs among females for the TMJ (15.3% vs. 22.1%,

15.4% vs. 16.7), this difference is not statistically significant (p = 0.20). The absence ofany joint areas with significant differences in the left and right sides of the skeleton suggest bilateral forms of activity, rather than repetitive activity that would cause a unilateral pattern of OA on the skeleton.

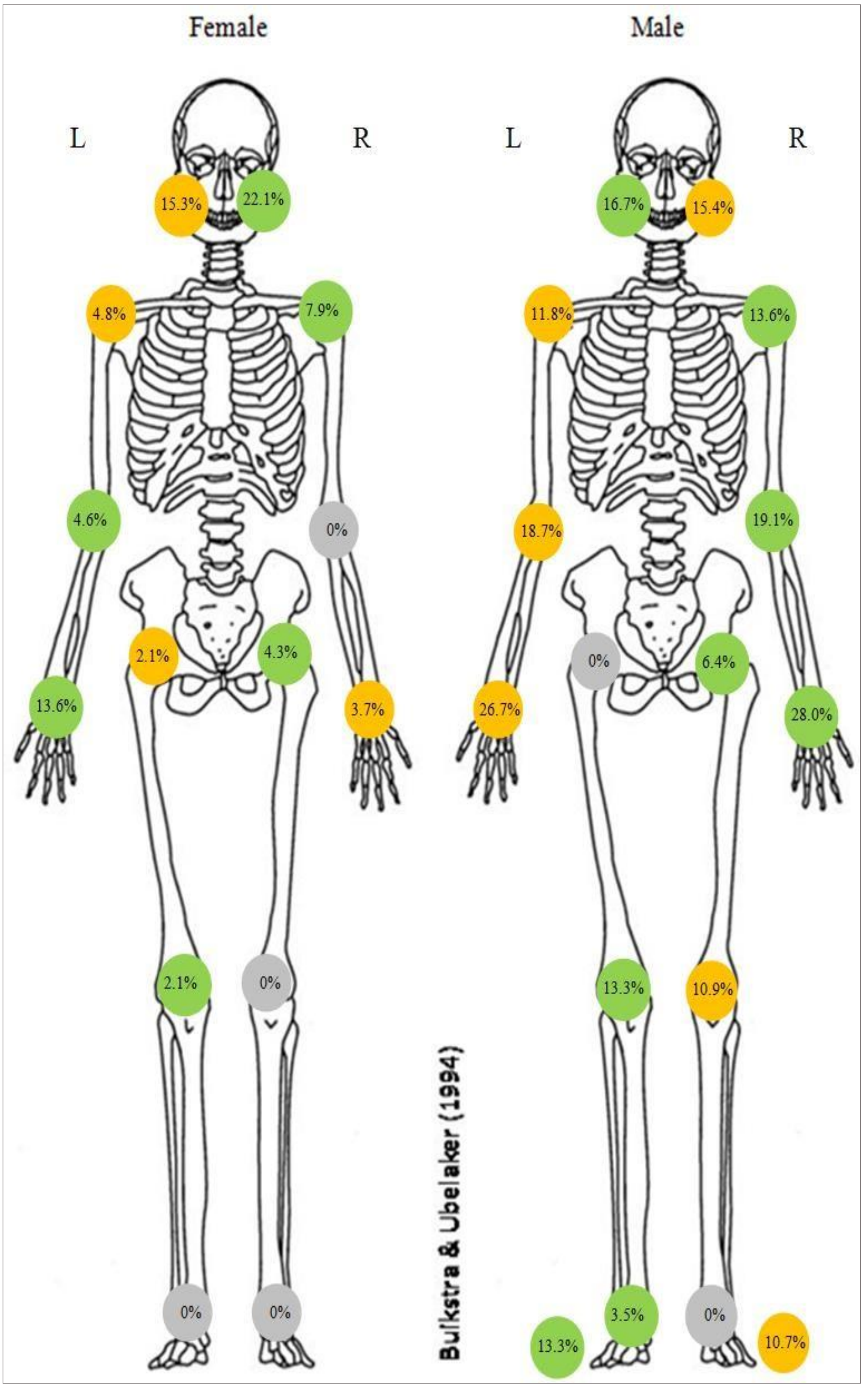

Figure 6.1 - Percentage of observed joints with OA (scored 1 to 3) on the left or right of joint areas that are scored 1-3 by sex. Green indicates a higher percentage in that joint area, yellow represents a percentage of 0.1% and above. Gray represents 0.0%.

6.3 Vertebral Degeneration

6.3.1 Vertebral Centra

In the vertebral centra, 42 individuals (42/90, 47%) have observed joint surfaces. These 42 observable centra are from 19 females, 21 males, and 2 individuals whose sex was indeterminant. These two individuals are excluded from further analyses of centrum vertebral osteophytosis (VO). In terms of observed vertebral centra, 50.3% (594/1,182) belong to the female group, and 49.7% (588/1,182) belong to the male group. A Fisher's exact test shows no statistically significant difference between the number of observed female and male joints given the number of male and female individuals (p= 0.75).

Table 6.12 shows the count of affected and unaffected individuals across sex categories, and the count of affected joints within these groups. Overall, 21 individuals (21/40, 50%) have VO present on the vertebral centrum. Females and males are near equally represented amongst those with VO, 53% (10/19) and 52% (11/21), respectively. Of the 21 individuals with VO present, only two have centrum VO alone. One individual is a female, and one is a male. Neither individual has any other observable joint degeneration upon the skeleton. Affected joints are 13% (151/1,182) of the total observed. Affected female centra are 9.4% (56/594) of total observed female joints in the centra, and male joints are 16.2% (95/588) of the observed male joints. While there are no sex-related differences in the frequency of VO among individuals, males have a higher chance of VO based on a count of affected joints (OR= 1.85, p = 0.0006).

Table 6.12 - Presence and absence of VO based upon count of joints and individuals by sex.

	Female		*Male*	
	Joint	Individual	Joint	Individual
Presence (Score1-4)	56/594	10/19	95/588	11/21
%	9.4%	52.6%	16.2%	52.4%
Absence (Score 0)	538/594	9/19	493/588	10/21
%	90.6%	47.4%	83.8%	47.6%
Total	**594**	**19**	**588**	**21**

Males have more joints of the centra with the presence of VO (score 1-4) and with higher severities. This is observable in the increased number of joints scored 3-4 in the male group (see Table 6.13 below). It must be noted, however, that the 5 joints scored 4 are all from one individual. A chi-square test was used to assess the relationship between sex and severity of OA using score 0, 1 and 2+. This returned a statistically significant relationship between sex and OA scoring ($\chi^2 = 14.4$, df=2, p= 0.0007).

Table 6.13 - Count of VO affected joints (score 1-4) and sex category and score.

	Score 0	*Score 1*	*Score 2*	*Score 3*	*Score 4*
Female	538	43	11	2	0
%	52.2%	41.3%	35.5%	18.2%	0%
Male	493	61	20	9	5
%	47.8%	58.7%	64.5%	81.8%	100%
Total	**1,031**	**104**	**31**	**11**	**5**
Total %	**87.2%**	**8.8%**	**2.6%**	**0.9%**	**0.4%**

6.3.1.1 Age and Sex

As VO is closely associated with age, examining VO distributions across age and sex categories together will better inform on the impact of age upon vertebral degeneration.

Table 6.14 Shows the count of affected against observed joints for sex and age categories. There are few differences on the frequency of affected individuals by age. Most affected individuals with VO are in the middle adult category. The differences in the affected individuals in the middle adult male and female groups is statistically insignificant (OR = 0.36, p= 0.58). The overall very low frequency of VO in the young adult group are expected.

Table 6.14 - Count of affected individuals and joints and percentages by age and sex categories.

	Young Adult		*Middle Adult*		*Old Adult*	
	Joint	Ind.	Joint	Ind.	Joint	Ind.
Female	0/197	0/7	23/310	6/7	11/16	2/3
%	0.0%	0.0%	7.4%	85.7%	68.8%	66.7%
Male	3/151	1/3	63/283	6/9	26/74	3/3
%	2.0%	33.3%	29.2%	66.7%	34.2%	100.0%
Total	**3/348**	**1/10**	**86/527**	**12/16**	**37/92**	**5/6**
%	**0.9%**	**10.0%**	**16.3%**	**75.0%**	**40.2%**	**83.3%**

Affected joints have a statistically significant difference by sex within two of the age categories. Middle adult males were 5.13 times (p= <0.0005) more likely to have joints affected with VO than females. This much higher frequency of male centra with VO reflects the influence of one individual. This individual has 31 affected joint surfaces, making up 49% (31/63) of middle adult male affected joints alone. Accounting for this one individual helps account for the similarity in frequency of VO among individuals by sex, but the apparently substantial different in likelihood of affected centra. In the old adult category, females have a higher likelihood of affected joints with an OR of 4.16 (p = 0.02). This difference is statistically significant and contrasts the middle adult group. However, there is a disparity in numbers of observed joints in the old adult category with males having many more observable joint surfaces than females. It is not possible to infer whether this difference in assessable joint surfaces might affect the difference in OR score.

6.3.1.2 *What area of the vertebrae are affected by VO.*

Joints were analysed by vertebral region in order to understand what the differences were between males and females and if any degeneration could be attributed to differences in activity. Table 6.15 shows the observed and affected individuals by vertebral region. Overall, the lumbar vertebrae have the highest proportion of affected individuals, followed by the lower thoracic and the cervical regions. None of these regions had frequencies of VO that differed statistically significantly by sex of individuals.

Table 6.15 - Count of affected and observed individuals by each vertebral joint region

	Female		*Male*		***Total***	
	Individual	%	Individual	%	**Total count**	**Total %**
Cervical	2/8	25.0%	7/18	38.9%	**11/27**	**40.7%**
Upper Thor.	1/7	14.3%	3/9	33.3%	**4/19**	**21.1%**
Lower Thor.	4/9	44.4%	3/7	42.9%	**8/19**	**42.1%**
Lumbar	6/12	50.0%	8/14	57.1%	**14/29**	**48.3%**
Sacrum	3/15	20.0%	0/12	0.0%	**3/28**	**10.7%**

Table 6.16 shows that when examining total observed and affected joints, VO has the highest overall frequency in the lumbar vertebrae (16.8%, 50/297) followed by the lower thoracic (LT) (14%, 32/222). There are some patterns that appear when joints are examined by sex. In the females, the sacrum has the highest percentage of affected joints, followed by the lumbar vertebrae. The next most common area is the cervical region where there are four joints (10%, 4/112), but these are found on only two individuals. Males share a high frequency of lumbar VO, however, the male group has a higher frequency of degeneration in all regions except the sacrum.

Table 6.16 - Count of affected and observed joint surfaces by sex and vertebral region.

	Female		*Male*		***Total***	
	Joint Count	%	Joint Count	%	**Total Joint**	**Total %**
Cervical	4/112	10.0%	21/150	14.0%	**25/262**	**9.5%**
Upper Thor.	1/96	2.1%	13/97	13.4%	**14/193**	**7.3%**
Lower Thor.	6/132	4.5%	26/90	28.9%	**32/222**	**14.4%**
Lumbar	18/150	12.0%	32/147	21.8%	**50/297**	**16.8%**
Sacrum	5/34	14.7%	0/24	0.0%	**5/58**	**8.6%**

The sex-associated differences just noted are reflected in the odd ratio scores of each vertebral region shown in Table 6.17. All joint areas, except the sacrum, show an increased likelihood of the male group being affected with VO with these differences being statistically significant.

Table 6.17 - OR and p-value scores by joint area and sex category.

	Cervical	Upper Thor.	Lower Thor.	Lumbar	Sacrum
OR	4.37	14.55	8.85	2.03	N/A
P-value	0.005	0.001	<0.0005	0.02	N/A

In three joint areas there is one outlier individual who alone influenced the OR score. In the cervical, Individual 584 has ten affected joint surfaces, which is 48% (10/21) of male affected cervical joints. The UT also shows a male (Individual 506) with seven affected joint surfaces, making up 54% (7/13) of male UT joint surfaces. In the lower thoracic (LT), Individual 534 had 16 affected joint surfaces, making up 61% (16/26) of affected joints. These biases are not seen in the vertebral regions of the female group. When these males are removed from each joint area, the new frequencies (see Table 6.18) tend to remain statistically significant, with the clear exception of the cervical region.

Table 6.18 - New VO frequency with removed outliers by joint area and sex, with revised OR and p-value scores. Changed scores are highlighted yellow.

	Cervical	Upper Thor.	Lower Thor.	Lumbar	Sacrum
Female	4/112	1/96	6/132	18/150	5/34
Male	11/140	6/90	10/74	32/147	0/24
OR	2.29	6.72	3.41	2.03	N/A
P-value	0.19	0.06	0.03	0.02	N/A

6.3.1.3 *Age and affected joint areas*

Table 6.19 shows the variation in affected joint surfaces by age and sex by joint region. Overall, the middle adult group of both sex categories shows the highest frequency of affected surfaces in all joint regions. There appear to be general age-associated trends in VO progression. The young adult group has low frequency in both sex groups, with increasing VO in the middle and old ages. Females, however, have increased variability over age that is not observed in the male group. This is especially so in the old adult group. This variability could be from the fewer observed joints in the old adult female group.

Table 6.19 - Affected joints (Scored 1-4) in the vertebral centra by joint area and age and sex categories.

	Young adult				*Middle adult*				*Old adult*			
	F	%	M	%	F	%	M	%	F	%	M	%
Cervical	0/47	0.0%	0/41	0.0%	2/61	3.3%	10/78	12.8%	2/4	50.0%	11/31	35.5%
Upper thor.	0/42	0.0%	3/26	11.5%	1.54	1.9%	3/26	11.5%	0/0	0.0%	7/15	46.7%
Lower thor.	0/48	0.0%	0/18	0.0%	6/84	7.1%	22/60	36.7%	0/0	0.0%	4/12	33.3%
Lumbar	0/45	0.0%	0/57	0.0%	11/98	11.2%	28/75	37.3%	7/8	87.5%	4/16	25.0%
Sacrum	0/16	0.0%	0/9	0.0%	3/14	21.4%	0/14	0.0%	2/4	50.0%	0/1	0.0%
Total	**0/198**	**0.0%**	**3/151**	**2.0%**	**23/311**	**1.8%**	**63/253**	**24.9%**	**11/16**	**68.8%**	**26/75**	**34.7%**

Female VO in the lumbar vertebrae has an increase from the middle adult to the old adult category, with old adult females being 51 times more likely to have lumbar VO than middle adult females (p = <0.0005). However, due to the low number of total observed joints in the old adult female group, this might be the result of sampling error.

Cervical VO present in the male group does reflect some increasing frequency with age. Old adult males are 3.68 times more likely to have joints with VO in the cervical vertebrae than middle adult males (p= 0.01). While females do have an increase in the frequency of affected joints in the cervical region across these age groups, these four joints with VO belong to only one middle adult, and one old adult female and cannot be reliably interpreted as reflecting a relationship with age.

6.3.2 Facets

In the vertebral facets 33 individuals (33/90, 42%) with confirmed age and sex have at least one observed joint surface. There are few differences in the count of observed individuals by sex, with females making up 45.5% (15/33) and Males 54.5% (18/33) of the sample. There was one individual of indeterminate sex, and four individuals of indeterminate age who were excluded from the sample. In total 959 joint surfaces were observed on the vertebral facets, which again have little difference between sex categories. Male observed joints make up 54% (519/959) of this number and females 46% (440/959).

Table 6.20 Shows the count of affected and unaffected joints and individuals by sex. Of the 33 individuals nine (27%, 9/33) have OA upon the facets. Males have double the frequency of affected individuals than females, however this difference is not statistically significant (OR =

2.12, p= 0.44). Compared to the other two skeletal regions, the facets have the lowest frequency of affected joints.

Table 6.20 - Presence and absence of vertebral facet OA based upon count of joints and individuals by sex category.

	Female		*Male*	
	Joint	Individual	Joint	Individual
Presence (Score 1-4)	8/440	3/15	14/519	6/18
%	1.8%	20.0%	2.7%	35.3%
Absence (Score 0	432/440	12/15	505/519	12/18
%	98.2%	80.0%	97.3%	64.7%
Total	440	15	519	18

Affected joints are 2% (22/959) of total observed facets. Of this female affected joints make up 0.8% (8/959) of observed joints, and male affected joints are 1.3% (14/959) of observed joints. There is no statistically significant difference in the frequency of affected individuals by sex. The difference in affected joints in the male and female groups are not statistically significant (OR= 1.50, p= 0.39).

Table 6.21 shows the frequency of affected joints by OA severity. A score of 1 (Small deposits) is the most common OA score observed, followed by score 2 (pitting). These scores are both of a higher frequency in the male group. Only the female group had joints affected with a score of 4 (other), however, these were all found on one individual (Individual 494) and were identified as flattening and lipping of the facets. They had no other facet pathology.

Table 6.21 - Frequency of affected facet joints by OA score and sex category.

	Score 0	Score 1	*Score 2*	*Score 3*	*Score 4*
Female	432	5	0	0	3
%	98.2%	1.1%	0.0%	0.0%	0.7%
Male	505	10	4	0	0
%	97.3%	1.9%	0.8%	0.0%	0.0%
Total	**937**	**15**	**4**	**0**	**3**
Total %	**97.7%**	**1.6%**	**0.4%**	**0.0%**	**0.3%**

A chi-square test was carried out to examine the relationship between OA score and sex. This was done with rows indicating score 0, and score 1+. This returned a statistically insignificant relationship between sex and joint score ($\chi^{2=}$ 0.85, df= 1, p= 0.36).

6.3.2.1 Age and Sex

Table 6.22 shows the count of affected individuals by age and sex category. There is no observable difference in the count of affected individuals in each age category when comparing the two sex categories. There is little difference in count of affected joints by age. While most affected joints are in the middle adult group, the old adults have the highest proportion of affected joints when compared to observed joints (7/102).

Table 6.22 - Frequency of affected and non-affected individuals by sex and age (Facet Joints).

	Young Adult		*Middle Adult*		*Old Adult*	
	Joint	Ind.	Joint	Ind.	Joint	Ind.
Female	3/116	1/5	5/260	2/7	0/22	0/2
%	2.6%	20.0%	1.9%	28.6%	0.0%	0.0%
Male	5/163	1/7	7/302	4/9	7/80	2/3
%	3.1%	14.3%	2.3%	44.4%	9.1%	66.7%
Total	**8/279**	**1/12**	**12/562**	**6/16**	**7/102**	**2/5**
Total %	**2.9%**	**8.3%**	**2.1%**	**37.5%**	**6.9%**	**40.0%**

There is no statistically significant difference in the frequency of affected joints between the sex categories. The old adult group has the clearest disparity in affected joints between sexes, as there are no observed female joints that indicate the presence of OA upon the facets. However, this difference is not statistically significant, and only two old adult males had affected joints.

6.3.2.2 Affected joint areas.

Joints were split by vertebral region in order to understand what differences there may have been between sex and age categories. Table 6.23 shows that the frequency of individuals with OA in the vertebral facets is low. Only three females have facet degeneration, and this degeneration is only present on the lumbar vertebrae. In contrast, males have affected individuals in all joint regions apart from the sacrum. Unlike the females, the male group has only one individual with OA degeneration in the lumbar joints. The cervical joints have the highest proportion of individuals with OA affected joint surfaces in the male group.

Table 6.23 - Affected and non-affected individuals by sex and facet joint region.

	Female		*Male*		***Total***	
	Individual	%	Individual	%	**Individual**	%
Cervical	0/6	0.0%	4/14	28.6%	**4/20**	**20.0%**
Upper. Thor	0/5	0.0%	1/10	10.0%	**1/15**	**6.7%**
Lower. Thor	0/6	0.0%	2/8	25.0%	**2/14**	**14.3%**
Lumbar	3/10	30.0%	1/11	9.1%	**4/21**	**19.0%**
Sacrum	0/13	0.0%	0/10	0.0%	**0/23**	**0.0%**

Table 6.24 shows that, overall, every joint region has an extremely low percentage of affected joint surfaces. While the lumbar and cervical joints have the highest proportion of affected joint surfaces, these are only 3.5% and 3.0% respectively. There is no degeneration within the sacral joints, and in all regions except the lumbar, males have evidence of degeneration where females have none. Only males have affected joints in the cervical facets, and in the sacrum, females have a statistically significant difference in affected joints when compared to males (OR= 8.61, p=0.02).

Table 6.24 - Affected and non-affected facet joint surfaces by sex and joint region.

	Female		*Male*		***Total***	
	Joint	%	Joint	%	**Joint**	%
Cervical	0/94	0.0%	8/175	4.6%	**8/269**	**3.0%**
Upper. Thor	0/94	0.0%	2/94	2.1%	**2/188**	**1.1%**
Lower. Thor	0/99	0.0%	3/94	3.2%	**3/193**	**1.6%**
Lumbar	8/127	6.3%	1/132	0.8%	**9/259**	**3.5%**
Sacrum	0/26	0.0%	0/24	0.0%	**0/50**	**0.0%**

6.3.2.3 Age and affected joint areas

Table 6.25 shows how OA in the facets varies by sex and age. The number of affected joints within the sample is very small, and there is no statistically significant increase in OA with age on the facets. However, the old adult male category has the highest frequency of OA overall. Cervical OA was observed in all male age groups, while only one middle adult male had thoracic OA and only one old adult male had lumbar OA. Also of interest is that young adult males have the highest frequency of cervical OA (5/56), even if affected male joints remains low. In the females, OA of the lumbar joints was observed among young adult joints (1 individual) and among middle adult joints (2 individuals). No other vertebral regions were affected.

Given the rarity of OA of the vertebral facets, it is unsurprising that there are no clear trends in the pattern of OA with age but the increased susceptibility of males to OA in thecervical vertebral facets is apparent in all age groups compared to females.

Table 6.25 - Affected and non-affected joint surfaces by vertebral facet region and age.

	Young adult				*Middle Adult*				*Old Adult*			
	F	%	M	%	F	%	M	%	F	%	M	%
Cervical	0/30	0.0%	5/56	8.9%	0/56	0.0%	2/102	2.0%	0/8	0.0%	1/17	5.9%
Upper thor.	0/32	0.0%	0/32	0.0%	0/62	0.0%	2/52	3.8%	0/0	0.0%	0/10	0.0%
Lower thor.	0/40	0.0%	0/13	0.0%	0/59	0.0%	3/71	4.2%	0/0	0.0%	0/10	0.0%
Lumbar	3/50	6.0%	0/53	0.0%	5/65	7.7%	0/64	0.0%	0/12	0.0%	1/15	6.7%
Sacrum	0/14	0.0%	0/9	0.0%	0/10	0.0%	0/13	0.0%	0/2	0.0%	0/2	0.0%
Total	**3/166**	**1.8%**	**5/163**	**3.1%**	**5/252**	**2.0%**	**7/302**	**2.3%**	**0/22**	**0.0%**	**2/54**	**3.7%**

6.4 Relationship between joint areas.

Table 6.26 shows how the individuals across the sample manifest OA across the skeleton. In both male and female groups, over half the observed individuals have at least one joint affected with OA (score 1-4). Females had a higher proportion of individuals who were observed but did not have any affected joints when compared to non-affected males, however, this difference is only four individuals. In both the male and female groups, individuals with OA present only on the non-vertebral skeleton make up the highest proportion of affected individuals, possibly because of increased opportunities to observed OA on these joint areas. This is followed by the count of individuals with degeneration both on the non-vertebral skeleton and the vertebral centrum. Also of note is that it is predominantly male individuals who have joint degeneration on all three skeletal regions when compared to females.

Table 6.26 - Frequency of affected individuals by sex and location of joint degeneration.

	Female		*Male*	
Area of degeneration	Individual	%	Individual	%
Non-verte. Only	12	32.4%	12	32.4%
Centrum Only	1	2.7%	1	2.7%
Facet Only	0	0.0%	1	2.7%
Centrum & Non-verte.	5	13.5%	4	10.8%
Facet & Non-verte.	1	2.7%	1	2.7%
Centrum & Facet	1	2.7%	2	5.4%
All regions	1	2.7%	4	10.8%
No OA/VO present	16	43.2%	12	32.4%
Total	**37**	**50.0%**	**37**	**50.0%**

There is no statistically significant difference in any location of OA when comparing the sexes. While the frequency of individuals with degeneration in all three skeletal regions differs more noticeably by sex than all other combinations of OA and skeletal region, it statistically insignificant (OR= 4.29, p= 0.36).

When the full skeleton is examined, females appear to have OA in only two significant locations – the TMJ, and the lumbar vertebrae (on both facets and centrum). Table 6.27 shows each individual with TMJ and lumbar degeneration and if they have both areas or one affected. In this sample, TMJ degeneration and lumbar vertebrae degeneration are almost mutually exclusive, with only one female having degeneration in both areas. There is no statistical difference in the number of individuals with degeneration in the TMJ when compared to the lumbar vertebrae (OR= 1.58, p= 0.73).

Table 6.27 - Female individual I.D by presence of Degeneration in TMJ and/or lumbar vertebrae.

Individual I.D	*TMJ*	*Lumbar*
372	✓	
379	✓	
418		✓
494	✓	✓
511		✓
532	✓	
541	✓	
549		✓
554	✓	
557	✓	
576		✓
595		✓
607	✓	
632		✓
636	✓	

There does not appear to be a correlation between age and where OA in the TMJ or lumbar vertebrae develops. Table 6.28 shows that most individuals are in the middle adult age category. However, the only individual with degeneration in both areas is a young adult. The middle adult category sees no statistically significant difference between individuals with TMJ or lumbar degeneration (OR= 1.52, p=1). In the old adult group, two individuals have TMJ OA, and one has lumbar degeneration.

Table 6.28 - Frequency of affected individuals by age group.

	Young Adult	*Middle Adult*	*Old Adult*
Individual I.D	494 554	372 379 511 541 549 595 607 632 636	418 532 557
Count	**2**	**10**	**3**
Count %	**13.3%**	**66.67%**	**20.0%**

If the two joint areas with the highest frequency in the female group (TMJ and lumbar vertebrae) were compared, only one individual had degeneration on both the TMJ and the lumbar vertebra. There is no positive correlation between presence of OA on the TMJ and presence of VO on the lumbar vertebrae.

Males have a broader distribution of where degeneration occurs upon the skeleton, including the TMJ, shoulder, elbow, wrist, and the cervical vertebrae. Table 6.29 shows how different male individuals have degeneration in these areas. There was no statistical significance in the likelihood of individuals with OA in only one of these joint areas when compared to individuals with OA in two or more of these areas (OR= 1. 20, p= 1).

Table 6.29 - Male Individual I.D by presence of Degeneration in TMJ and/or cervical vertebrae.

Individual I.D	*TMJ*	*Shoulder*	*Elbow*	*Wrist*	*Cervical*
281			✓	✓	✓
334					✓
374			✓		
403					✓
497				✓	
506	✓	✓		✓	✓
533		✓		✓	✓
538		✓			
539				✓	
556		✓	✓		
573	✓		✓		
584	✓	✓	✓	✓	✓
585				✓	
586	✓				
588			✓	✓	
605		✓	✓		
613		✓			✓
634		✓	✓	✓	✓

There is no statistically significant difference in the males who have a combination of cervical vertebrae degeneration and shoulder OA, and males who only have degeneration on one of these areas (OR=0.52, p= 0.68). This is the same for individuals who have OA on the elbow and wrist (OR= 3.81, p= 0.14). Only the shoulder and elbow are statistically significant, as males are more likely to have OA on only one of these joint areas rather than both (OR= 14. 11, p= 0.003). There is no distinct combination of OA that appears in these joint areas.

Table 6.30 shows the distribution of age across the individuals with OA in the aforementioned joint regions. The middle adult group makes up the highest proportion of individuals. OA upon these joint areas does not depend upon age alone. While two of the old adult individuals have OA upon the TMJ, shoulder, wrist and cervical vertebrae, two only have one joint region affected.

Table 6.30 - Frequency of affected individuals by age and individual I.D.

	Yg. Adult	*Mid. Adult*	*Old Adult*
Individual I.D	403 539 573	281 334 374 497 533 556 585 588 605 613 634	506 538 584 586
Count	**3**	**11**	**4**
Count %	**16.7%**	**61.1%**	**22.2%**

6.5 Individuals of interest

There are two key individuals of interest within this sample. One individual has the highest frequency of affected joints of the entire sample. One individual has OA that does not correspond with the patterns of OA.

6.5.1 Individual #634

This individual, a middle adult male, is of interest because of the number of affected joints found upon their non-vertebral skeleton and their vertebral centra. This individual has a total of 112 observed joints on their skeleton. Of these joints, 43 (38%, 43/112) are affected by joint degeneration.

In the non-vertebral skeleton, this individual had 54 joints observed and 12 affected with OA, predominantly in the elbow joints. As the elbow had observable OA in numerous male individuals, so OA presence alone is not significant. This individual makes up 30.4% (7/23) of affected male elbow joints, with degeneration in both the left and right, yet almost no other non-vertebral skeleton joints were affected by degeneration in this individual.

Across the vertebrae, this individual has 58 joints observed, and 31 affected with VO. In the vertebral centrum, every observed joint surface from T8 to L3 had VO present. While the total male group does have a high frequency of lumbar and lower thoracic VO, no other male has this level of degeneration upon the centrum. If odds ratios were used to examine the likelihood of this male having VO when compared to the rest of the observed males, the result is statistically significant (OR= 5.80, p= <0.0005).

This individual may have had some form of disseminated infection, which could explain the high frequency of degeneration throughout their skeleton. However, their degeneration, while widespread across the vertebral centrum, is absent from the vertebral facets and only of a high frequency in the elbow.

6.5.2 Individual #576

This individual, a middle adult female, is most reflective of possible gendered patterns of OA. They have degeneration on both the vertebral centrum and the non-vertebral skeleton, and have patterns of OA that, when compared, are not reflective of other females.

In the non-vertebral skeleton, female OA is predominantly found in the TMJ. The male group has a more widespread frequency of OA, with OA also being in the shoulder, elbow, wrist, and feet (See table 6.10). This individual is one of two females with OA in the shoulder. To be more specific, this individual is also the only female to have OA on the sternoclavicular (SC) and acromioclavicular (AC) joints. In contrast, six male individuals have OA on one or both of these joints. In this sample, the SC and AC are distinctly male in their degeneration. This individual is also one of only two females who have cervical VO in the centrum. This is compared to 7 males with cervical VO. Individual 576 has VO present on C3 only, and while there are two other males with C3 VO, because of the variability of where cervical centrum VO is present in the male group, the specific vertebra does not have any significance regarding degeneration.

This individual is of interest because with the combination of degeneration within these joint areas, their skeletal degeneration more closely aligns with the male group than the female group, and thus is the clearest possible representation for recognisable gender within this sample.

6.6 Summary

Males overall have more affected individuals, and more affected joints per individual than the female group. On the non-vertebral skeleton, all joint areas see a gradual increase with age in both males and females. However, the TMJ and elbow do have affected joints in the young adult group. Females have the highest frequency of joints only on the TMJ, whereas males have a higher frequency of affected joints on the shoulder girdle, elbow, and wrist. The lower body has a low frequency of OA, but it is higher in the male group than the female. The vertebral centra has a higher frequency of OA than the facets but both share a similar distribution. Males and females have a similar frequency of lumbar degeneration, however, males have a higher frequency of affected joints in the cervical vertebrae. This analysis reflects some clear differences between the male and female groups, however, one female does show degeneration that more closely resembles the male group.

Chapter Seven: Discussion

The pattern of osteoarthritis found at Roonka Flat captures the pathological joint degeneration of a long-spanning and diverse group of individuals buried at the site. While there is individual variation found in the patterns of osteoarthritis at the site, this sample reflects some marked differences between the sexes, and some similarities. The individuals from this sample share the same geographic range but span several thousand years of the site's occupation. However, meaningful information regarding broad divisions of labour between the sexes can still be gathered. This discussion will compare the osteoarthritis and osteophyte results presented in chapter seven to other studies of osteoarthritis in Australia and other hunter-gatherer societies.

7.1 Osteoarthritis at Roonka

OA at Roonka has a relatively low frequency, based on both affected individuals and affected joint surfaces. Hunter-gatherer communities are often associated with higher frequencies of OA when compared to agriculturalist or sedentary communities (Cohen & Armelagos, 1984; Bridges, 1992). However, Australia has low OA even compared to other hunter-gather sites (Webb, 1984; Merbs, 1983). The people with OA interred at Roonka reflect differing manifestations of the disease amongst both age groups and sexes, from which differences in activity may be understood.

When examining where OA develops on the skeleton, only the TMJ and the lumbar vertebrae have shared patterning between the sexes. Degeneration on the lumbar vertebrae is common and most reflective of life-long weight-bearing upon the spine (Niosi & Oxland, 2004). Because of this, the causes of lumbar vertebral degeneration are indistinguishable from processes of age. OA, as a result of repetitive activity, is best observed in joint areas that have observable degeneration by age, as this is most suggestive of repetitive motion throughout one's lifespan (Molnar, Ahlstrom & Leden, 2011). The young adult category does not differ between males and females, with a similar frequency of affected individuals and joint surfaces. Both young adult males and females have degeneration of the wrist and elbow. Although the pattern of OA in the young adult group shows the early formation of patterns visible in the middle and old adult categories, how these joint areas are affected with age differs between the sexes. OA as a product of activity intensifies more suddenly in the male group than in the female. Of note, however, neither males nor females have any form of significant asymmetry in any joint of the skeleton, meaning the activities people were carrying out did not favour either side. While spears were used around the Murray, both for fishing and for hunting big game (Eyre, 1845; Hill et al, 2020), evidence of their use is not visible through OA alone.

In the wider skeleton, females have much higher heterogeneity in where OA occurs than males. Heterogeneity here refers to the absence of distinguishable clusters of degeneration seen in the male group. Only the TMJ and the lumbar vertebrae show homogeneous degeneration, not only by the number of affected individuals, but also in how it is affected across age categories. While most areas of the female skeleton have at least one affected individual, these individuals have a low frequency of affected joint surfaces in which there is no clear distinction of a socially influenced pattern of OA (See table 6.11). The TMJ is the only joint in the female group that is clearly socially influenced. Along the river, women would have typically carried out gathering, small game hunting, and fishing (Eyre, 1845). Extra-masticatory activity would have been commonplace in the production tools commonly used by women, including digging sticks and dilly-bags (Trow, 2017). Twine creation would have also been done to create nets, clothing, and baskets. However, the arm motion that would accompany extra-masticatory behaviour is not evident in this female group, judging by frequencies of OA in relevant joints. This absence of elbow OA suggests that females did not carry out extra-masticatory stripping of material, but instead the chewing down of fibres that were then rolled along the thigh to make twine (Figure 7.1) (Eyre, 1845; Kaberry, 1939). While both methods included extra-masticatory behaviour, they represent a difference in pathological embodiment.

Figure 7.1 - Making string by hand by rolling two fibres together on the thigh. (Philip A. Clarke, Galiwinku, Elcho Island, northeast Arnhem Lane, Northern Territory, 2010).

All other joint areas lack a clear pattern of OA in the female group. This is especially noticeable when considering age and how OA is distributed across these joint areas. The TMJ is the only joint consistent across all age categories, reflecting continuing and progressive development of TMJ degeneration. No other joint surface shares this degree of affectedness in the female group, even if age is removed as a variable and joint area is examined alone. Beyond the TMJ and the lumbar vertebrae, the female group has no joint area that shows progressive degeneration, limiting how one can interpret those joint areas as social activity rather than individual variation.

Males (per individual) have almost three times the frequency of affected joints when compared to the female group (See table 6.6). In the male group, the TMJ, joints of the shoulder girdle, elbow and wrist are all affected by higher rates of OA. These joint areas, alongside degeneration of the cervical vertebrae, suggest increased strain on the upper body in the male group not observed across the females. Male-dominated activities at Roonka would have primarily involved fishing and riverine activities, and similarly to women, TMJ degeneration suggests extra-mastication (Eyre, 1845; Berndt & Berndt, 1964). Because of the degeneration also seen in the elbow and wrist, it is possible that this extra-masticatory behaviour included stripping of hide and fibres, alongside chewing down. This is opposed to females who may have only chewed down these fibres, based upon the absence of elbow OA that would be expected toaccompany this movement.

The most affected joint surfaces in the shoulder are the sternoclavicular and acromioclavicular joints. These joints suggest a pulling motion or rotation of the clavicle rather than rotation of the humerus as the cause of this degeneration (Mazzocca, Arciero & Bicos, 2007). While acromioclavicular degeneration is prevalent in today's elderly populations (Waldron, 1995), degeneration of this kind is associated with activity that may cause repetitive axial impact, such as swimming, basketball, or weightlifting (Mall et al, 2013; Menge et al, 2014). In the Roonka sample, it is found primarily in the male group (and one female), suggesting a social contribution to degeneration of these joints. These activities all include the active motion of raising the arm above the head and holding it there. While men at Roonka would have partaken in activities that caused strain upon the arm, such as net-hauling and load-carrying (Eyre, 1945), pinpointing the specific activity that may have caused this degeneration is beyond the information OA can provide. Corresponding with degeneration of the clavicle, cervical vertebral degeneration is consistent with this strain on the upper body and, similarly, shows continuing progression by age. These areas show increasing progression and a relatively stable frequency across age categories, suggesting long-term contributing factors causing degeneration upon these joint surfaces.

7.1.2 Are these differences between the sexes expected?

On a broad level, the differences between the sexes can be expected based on research from other hunter-gatherer sites, both in Australia and elsewhere (Merbs, 1983; Webb, 1984; Lieverse, 2007; Carlson, Grine & Pearson, 2007). In comparing different hunter-gatherer groups around the globe, Carlson, Grine & Pearson (2007) found that all observed male and female groups differed in their long bone robusticity in a way that could be attributed to differences between the sexes. This included upper limb differences attributed to differences in weight-loading and tool use, such as spear-use, digging sticks, and the transportation of heavy loads (Carlson, Grine

& Pearson, 2007; Schmitt, Churchill & Hylander, 2003). Webb (1984) similarly finds this in different Aboriginal Australian populations and suggests that, based upon his findings of osteoarthritis, male activities were more strenuous than females.

These differences in the upper body are not observed in the lower body. Carlson, Grine & Pearson (2007), Webb (1984) and Lieverse (2007) all found low frequencies of degeneration in the lower body. Although Roonka reflects this low frequency, male OA on the lower body is higher than the female group. The differences in lower limb OA between the sexes have been attributed to differences in mobility (Hilton, 1994; Hilton & Greaves, 1995; Carlson, Grine & Pearson, 2007). However, given the similarities in mobility between males and females within a hunter-gatherer group, these differences at Roonka cannot be explained here (Carlson, Grine & Pearson, 2007; Webb, 1984).

The unexpected variation found in the female group compared to the male group suggests that female individuals buried at Roonka had greater flexibility or variation in their daily activities than males. One possibility for this apparent variability is that female activities were less strenuous upon the joints than male activities, even if labour was carried out equally. Processes of gathering often included long hours of movement, the use of the digging stick, and the possibility of carrying heavy loads (Abbie, 1969; Berndt, 1978). While the combination of these activities would have changed seasonally (Meehan, 1975), each would still have been regularly carried out. While female activity may have been less strenuous, Aboriginal Australians also are not predisposed to arthritic degeneration. Other common forms of arthritis, like rheumatoid arthritis or ankylosing spondylitis, only appear in the Aboriginal Australian pathological record post-contact (Roberts-Thomson & Roberts-Thomson, 1999). The variability of female degeneration could be explained in the context that if activity was less strenuous on joint systems, then OA in most individuals may not have had time to develop beyond soft tissue inflammation.

There is a possible ethnographic explanation for this variability in where female OA is located upon the skeleton. ‘Wife-exchange’, in which women would move to their husband's community to strengthen inter-group relationships, resulting in increased female migration that could explain this variability (Malinowski, 1913; Kaberry, 1939). Kaberry (1939) describes girls as young as ten being sent to live in a different community, and Eyre (1845) describes how children would follow their mothers if they were migrating. Although younger girls would reflect patterns indicative of their new community, older females who migrate could indicate OA reflective of both old and new communities. This could mean that the female OA observed in the sample represents more regional patterns of OA, whereas the male group is a more localised representation. While there is no reliable way of determining this specific migration in this sample, this theory may explain why OA is so variable by joint area and age in the female group. While there is some male variability in this sample, patterns of distinct clusters of affected joints are evident in the male sample in such a way not observed in the female group.

With that in mind, the Roonka burial site was likely used by multiple groups over a long period of time. Given that the earliest periods of the site show only males and children buried, the area may also be reflective of differential burial practises (Littleton et al, 2017a; Littleton, Karstens & Allen, 2021; Pretty, 1977). Littleton et al. (2013) also suggest that the diversity in burial positions possibly indicates different burying groups, even if these groups are not from different populations. The Roonka site was occupied over an 8000-year period, with OA at the site being one type of pathology amongst a diverse group of people. Although time is an important variable to consider at a site such as this, to properly assess the differences in activity and how gender may play a role in these differences, all individuals with OA were included in the sample regardless of the time period in which they lived.

7.2 Roonka contextualised

In Australia, it is primarily Webb who provides osteoarthritic information about past Aboriginal populations. While Webb never used the Roonka collection within his analyses, he did use co-mingled samples from across the surrounding Murray region. The Murray (Central

Murray and Murray Valley) region was the only area where females had a higher frequency of TMJ OA than males (63.4% and 50.9%, respectively) (Webb, 1984). Roonka had a lower frequency than upriver. However, the differences between the sexes are similar (See table 6.11). Age in this sample also plays a noticeable role in TMJ degeneration. It is observed in the young adult group of both sexes, indicative of early use and learning of activities involving the TMJ. Although most regions examined by Webb (1984) have some form of TMJ degeneration, the degeneration seen along the Murray was argued to show increased stress and intensified use of the TMJ.

TMJ OA is likely driven by the creation of textiles and twine for the production of nets and baskets (Griffin, Powers & Krszynski, 1979). In a riverine environment, nets, both the creation and use of, would have significantly contributed to subsistence behaviours (Fig. 7.2). Dentition and dental wear at Roonka support the extensive use of extra-masticatory behaviours of both males and females, suggesting that the patterns observed at Roonka are indicative of a shared or flexible labour process (Trow, 2017; Littleton, 2017; Littleton et al, 2013).

Figure 7.2 - Domestic occupations in the summer season on the Lower Murray River. Plate 41 from Blandowski's 'Australien in 142 Photographischen Abbildungen' (1862). Reproduced with permission of the Haddon Library, Faculty of Archaeology and Anthropology.z

In the postcranial skeleton, Webb (1984) only examined OA of the elbow and the knee, so these will be utilised as the point of comparison. Webb found that the Murray and Central Murray regions had the highest frequency of joint surfaces affected by OA across all the sites he examined (Webb, 1984). Focusing on the elbow, there is no marked difference in the male samples in both the Murray and Roonka groups. However, looking at the female samples, differences can be seen (Table 7.1). Whilst Roonka females have a lower frequency of affected joints in the elbow than the Murray group, Webb also observed fewer total joints than were available at Roonka. Given the similar frequencies of elbow OA in the central Murray, Webb suggests that the use of the arm was a significant part of subsistence labour in both sexes, and that both malesand females of the Murray had bilaterality of the arm.

Table 7.1 - Frequency of affected Elbow joint surfaces by Sex at Roonka and the Central Murray frequencies provided by Webb (1984).

	Roonka	*%*	*Central Murray*	*%*
Females	4/130	3.1%	7/66	10.6%
Males	23/127	18.1%	20/161	12.4%
Total	**27/257**	**10.5%**	**27/227**	**11.9%**

Webb argued that this elbow degeneration resulted from activity more so than age, and that the frequency of elbow OA at the Murray indicates intense and repetitive arm movement (Webb, 1984).Webb emphasises the use of spear-throwing as a contributing factor to elbow OA. Although he does not describe what females may have undertaken, he suggests that female OA of the elbow reflects equal participation in their labour. (Webb, 1984). OA at Roonka indicates a bilateral arm use in both sexes, similar to that observed by Webb, while also indicating that female use of the arm was not a significant aspect of regular labour.

Both Hill et al. (2019, 2020) and Carlson, Grine & Pearson (2007) find increased diaphyseal robusticity on the humeral and radial midshafts in males compared to females. While Carlson, Grine & Pearson (2007) use a random skeletal sample from across Australia, Hill et al. (2019; 2020) focuses directly on Roonka for this comparison. Like Webb’s osteoarthritis analysis, there is little evidence of unimanual loading at the Roonka site. Hill et al. (2020) concluded that in females, the patterns of activity on the upper limbs result from digging sticks and grindstones. While digging sticks have been observed in the area (Eyre, 1845) and can play a role in riverine subsistence (Flood, 2001), no evidence of grindstone use has been found at Roonka. However, evidence of their use has been found upriver in the central Murray/Mallee (Littleton, Karstens & Allen, 2021). The female elbow degeneration that would reflect grindstone use, unlike females of the central Murray where grindstones have been observed, is also missing at Roonka (Webb, 1984; Littleton, Karstens & Allen, 2021).

When examining the lower body, every site examined by Webb (1984) had a less than 10% total involvement of osteoarthritis on the knee. This is consistent with the low frequency observed at Roonka (Table 7.1). Given this, age does not play a significant role in the development of knee OA, given the similarities between the sexes. However, because the lower body strain upon male and female hunter-gathers would have been similar (Carlson, Grine & Pearson, 2007), determining the root cause behind the differences in knee OA is not possible based on OA alone.

Table 7.2 - Frequency of affected knee joint surfaces by Sex at Roonka and the Murray (Combined frequencies of Central Murray and Murray Valley) (Webb, 1984).

	Roonka	*%*	*Murray*	*%*
Females	1/90	1.1%	1/67	1.5%
Males	9/143	6.3%	12/199	6.0%
Total	**10/233**	**4.3%**	**13/266**	**4.9%**

The absence of lower body osteoarthritis is not unexpected, as evidence from hunter-gather sites across the world has presented a low prevalence of OA in the knee as commonplace. (Lieverse, 2007; Zhang et al, 2017; Webb, 1984). Evidence also suggests that on the lower body, differences between the sexes are low when based on the extent of dimorphism in long bone diaphyses (Carlson, Grine & Pearson, 2007). Recent research has found that routine activity, like that carried out in hunter-gatherer societies, could prevent OA by strengthening joint systems (Berenbaum et al, 2018; Wallace et al, 2017; 2022). This does not disregard the useof OA as an indicator of activity. However, it does raise the question of how such patterns developed on the joints they did, especially within a group that shows low proportions of OA. Activity from a young age will result in stronger joint systems (Wallace et al, 2022), and in an Aboriginal context, this would be true for young children continuously travelling with their mothers while their mothers worked (Bell, 1981). Males see a higher proportion of lower body OA than females, even though a similar amount of strain would have been conducted on these joints. While there is evidence that activities that increase load upon the knee, such as kneeling, can contribute to OA of the knee and feet (Schram et al, 2020), it is unlikely that these activities would cause a disparity in a hunter-gatherer community.

In his research into Aboriginal pathology, Webb attributes the increased OA of the lower limbs in the male group to be a result of males having higher activity levels and dying at a later age (Webb, 1984). Not only did males have more OA than females, but Webb had fewer old adult females as part of his sample. Given that differential burial location was often carried out, old adult females are also less reliably found in the skeletal record, often due to issues of preservation (Agarwal, 2012). While there is no evidence at Roonka to suggest that females were dying sooner (given the distribution of individuals within each age category of the sample), this interpretation has its faults. However, when interpreting Webb's analysis, wider issues can affect comparison. First, Webb is working with co-mingled remains. Thus, OA across individuals cannot be examined like what was done in this study. Then, in comparing Roonka to Webb's analysis of the central Murray and Murray valley, the Murray remains he is using have no provenance. Although he did not use remains from Roonka in his analysis, there is no understanding of where these remains were from in comparison to Roonka, beyond being from the Murray region.

7.3 Gender at Roonka

The Roonka sample has made indications that although there were gendered activities within Roonka society, there was flexibility. People at Roonka could carry out ‘gendered’ activities regardless of their sex. Ethnographic work from across Australia reports flexibility and shared experience of labour from numerous communities across Australia. Meehan (1975), Bowlder and Balme (2010), and C. Berndt (1970) all indicate that although there were broad gendered differences in activity, these differences were flexible and opportunistic. Bell (1981) argued that people did not view labour itself as gendered, but more so that the spaces in which this labour occurred was gendered. Women’s-space and men’s-space were integral to the division of labour, and it was within these spaces that labour was carried out. Although these groups may have been associated with specific activities (such as hunting or gathering), people would have carried out different activities as needed (Kaberry, 1939). This goes against the strict gender roles that have been historically applied to hunter-gatherer communities.

This flexibility brings into question the role of the individual when examining osteoarthritis at Roonka. While the individual can often disappear when examining general patterns of a group (Heiss & Piette, 2015), the variation and flexibility known to occur in Aboriginal subsistence activities can only appear with individual people. Addressing the people who reflect this variation of labour is important, not only to better understand how activity and labour were carried out, but also to add depth to our interpretations of the past.

When examining gender in the past, often attention is spent on the patterns among the group, rather than examining individuals themselves. However, the individuals who stand out can become our biggest indicator of gender within the skeletal record (Agarwal, 2012). Sociocultural influences of the body are not layered on top of sex and age, but more so determine and mould sex- and age-related bone health (Agarwal, 2012). When examining the sample, gender at Roonka indicates differences in labour between men and women. Variability within these differences is where gender appears and where our understandings of gender at Roonka may be made.

Dental analysis at Roonka has provided the most extensive insights into gender. Trow

(2017) is the only study (at this time of writing) that focuses directly upon gender in the skeletal record at Roonka. Trow, using dental microwear, found no difference between the sexes that could reflect gendered activities. Degeneration of the TMJ in this sample is akin to Trow's. It displays a homogeneity of dental wear that indicates extra-masticatory activities were carried out almost equally. Littleton (2017a) also found that although males and females had the same level of anterior dental wear, females have more variation in the degree of anterior wear, similarly reflected in the wider distribution of OA within the sample. However, there is no guarantee that what is being examined in the skeletal record is indicative of gender.

The variability within the female group suggests an aspect of women's lives that men did notexperience. Eyre describes the myriad of shared activities that both girls and boys would have carried out by "learning the occupations and pursuits of after life, as to make twine, and weapons; to ascend trees; to procure food; to guide the canoe, and many other things" Eyre, 1845: 83). Differences in age initiation would mark the progression from juvenile to adult (Eyre, 1945; Berndt, Berndt & Stanton, 1993; Durband, Littleton & Walshe, 2014; Littleton, 2017a). Given the similarity of OA between the sexes within the young adult group in the elbow and TMJ, the age progression seen in both males and females is observable. However, the female variability compared to the males suggests that female activities were less strenuous upon joint systems, or that females had more freedom in the activities they were able to carry out.

One individual at Roonka who epitomises this variability is individual 576. Individual 576 (See 6.5.2) represents two possibilities. The first is that labour and flexibility influence how gender may be interpreted, or that 576 represents an extended gender binary. However, this then raises the question of whether one individual from a relatively small sample is indicative of a whole gender category. This is especially relevant given the existing variability within the female group. There are observed differences in males and females at Roonka, and all are important as they differentiate sex from culturally meaningful gender roles. However, the similarities between the sexes, both overall as seen in the TMJ, or those found across individuals, indicate that labour wasnot strictly gendered. This does not prevent other aspects of life from being gendered, such as religious or ritual practises (Bell, 1981; Kaberry, 1939; Berndt & Berndt, 1964), but represents an aspect of life that can be quickly affected by wider influences. This makes flexibility almost a necessity of Aboriginal subsistence.

7.4 Considering gender more broadly

When considering gender in the skeletal record, the issue lies in determining what gender is, and what is a consequence of flexibility, individual predisposition, or migration. When approaching activity as a basis for understanding divisions of labour, and the role of gender within this, divisions of labour by sex is presumed rather than approached as an aspect of social structure (Conkey & Spector, 1984). Aboriginal Australian societies in early literature were quickly assigned to pre-conceived notions of hunter-gatherer communities. These stereotypes have persisted and are still being grappled with today (Ames, 1999). While the individuals at Roonka are good examples of differences in activity between males and females, as observed through differences in joint degeneration, the Roonka sample is also reflective of the relationship between gender and labour not being as rigidly adhered to as first stereotyped by researchers and scholars alike.

Because of the flexibility observed in many Australian hunter-gatherer societies, questions arise on how to best describe individuals within a sample who are unique to others of their sex. Individual 576 is the best example found in this study. As a woman with degeneration more similar to males within the sample, 576 stands out as unique compared to the broader sex categories. There then remains the question, is this individual representative of an expanded gender binary, or are the affected joints in this individual more so a result of the innate flexibility of subsistence roles?

It is important to address questions surrounding the gendering of work, particularly if the work carried out by people at Roonka is inherently gendered; is the work people are doing driven solely by gender as a social variable? Within Australia, many have shown that this is not the case, and that work itself is not the gendered aspect of the activity. It is the context of the activity, the workspace, that is gendered in nature. The time spent working is carried out alongside others of the same gender (Bell, 1981). This, in turn, would influence how work is enacted. Whom a person interacted with would influence not only the activities they would have carried out, but it was likely indicative of how they perceived their place within society. One individual in the sample having such distinctions to others of the same sex is important. If OA is simply a result of the flexibility of labour, then this individual would likely not stand out as they do, as others would likely have OA of a similar distribution or location.

That being said, whilst we can conclude this individual's sex as female, the gender of this individual can never be determined. Precolonial Aboriginal gender has no existing record, and regional cultural differences make it problematic to assert a blanket statement on gender roles across Aboriginal societies. This sample clearly reflects shared responsibility between the male and female groups in the individuals excavated at Roonka, and broad gendered differences in activity that vary by individual. Aboriginal people today seek out a de-colonised gender binary and argue that an extended gender binary existed, only to be lost through the processes of colonialism (The Hook Up, 2018; Moon, 2020). However, in addressing precolonial gender from a post-contact perspective, studies of gender often try to give a name to something that unfortunately no longer exists in the way it once did. While attempting to further our understanding of gender as an ever-changing and flexible aspect of social organisation, it is essential to include indigenous perspectives in such a conversation. This is to try and understand how gender influences different aspects of daily life and, in turn, how gender is affected.

Conclusions

Osteoarthritis at Roonka shows a complex difference between the group and the individual. As a whole, males and females show variation in the frequency of affected joints and where OA develops. This indicates that some gendered activities differed between the sexes. However, an individual level reveals variability in these patterns. One female, in particular, has OA that is more reflective of the male sample than the female. This unique variation, only seen with 576, could have two plausible explanations.

The first is that activity was split mainly by gender, but within this, the division of labour was not strict, and many gendered activities were flexible when needed. The second possibility is that while there were two overarching recognised genders, there was a possible third gender, the definition of which was lost through colonialism.

While OA does suggest divisions of labour by gender between men and women with flexibility of labour, the organisation of OA at this site is from a group of individuals who lived over a span of 8000 years. Further research is needed to better understand these differences in activities over time.

By seeking an understanding of gender, osteoarthritis has revealed where key differences between male and female patterns of activity exist and where gender exists within this. However, this cannot then be applied to broader Australia. The regional, environmental and cultural differences would affect how labour differed across these regions and how gender was viewed and organised. Gender across precolonial Australia cannot be viewed as homogenous, and doing so would only negatively affect future studies on the topic.

However, the variability within the sample cannot be ignored, and osteoarthritis is only one aspect of pathology. Further studies will only continue to clarify the picture of gender found at Roonka. Therefore, this analysis provides evidence of gendered differences of activity at Roonka, within which individuals may vary and differ from others of their sex. While the existence of gendered roles exists here, these are not fixed nor should they be approached as such. Gender cannot be understood from OA alone, although insightful, will be expanded upon in the future.

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