

Assessment of disability resulting from degenerative joint disease in a southern African skeletal population

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DECLARATION

I, **Jessica Gavin**, declare that this Dissertation is my own, unaided work. It is being submitted for the Degree of **Masters of Science (Medicine)** at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

27th day of November 2023, at the University of the Witwatersrand, Medical School.

Note From the Author

Disability can affect anyone, but everyone affects disability.

The theme of this body of work premises that while some individuals experience disability themselves - *every* human interacts with and influences disability. This can be in seemingly insignificant daily interactions, such as a family relative who is living with an impairment type, or valuable ones, such as lawmakers deciding what is deemed insignificant for these individuals. In order to ensure that we do not lose these voices, it is vital to keep expanding and broadening knowledge on the topic of disability. Research offers an opportunity to start paving the way for transformation, protection, and understanding of a community that is currently underwhelmingly overlooked - all in the hopes of creating a positive change in society.

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Thank you.

ABSTRACT

Age-related skeletal changes, like degenerative joint disease (DJD), are often used to estimate age in forensic settings, yet these changes also reflect the living experience of individuals as they progress through life. This study set out to assess the impact of DJD in a sample of southern African deceased individuals and the subsequent effects on these individuals' Activities of Daily Living (ADLs). A novel scoring system was created, translating DJD frequency and severity into how the individual was potentially physically disabled.

A sample of 150 southern African individuals between the ages of 35 and 90 years were assessed for signs of DJD in each of the major joints, both for the peripheral (TMJ, shoulder, elbow, wrist, finger, hip, knee, ankle and toe joints) and axial (cervical, thoracic and lumbar vertebral joints) regions. The severity of DJD was then translated into various ADLs (transferring, eating, talking, object manipulation, walking and posture changes: head rotation; twisting and bending) that may have been affected. Socio-economic Status (SES) was included as this would have a significant impact on the types of DJD and subsequent ADL impairment seen, as well as how these individuals may have been impacted within their respective contexts.

Results for DJD severity and frequencies indicated that the shoulder most often presented with the most severe DJD score with 42.67% of the pooled sample presenting with a score of 3. It was also interesting to note that most of the upper peripheral joints were affected, with the entire sample presenting with some form of DJD in the elbow, specifically. For the axial skeleton, severity scores were much more variable across different vertebral regions, with the highest severity percentage per region was seen in the thoracic vertebra (5%). In general, females presented with higher severity scores for DJD across all joints, with the TMJ (47%) and toe (22%) joints being statistically higher in females. When controlling for population affinity and sex the same trend was observed in the white sample, specifically the white females (TMJ = 22%). Black males; however, presented with higher severity frequency of DJD in the axial skeleton, specifically the lumbar vertebrae (32%). The white cohort showed very little correlation with age in relation to the TMJ, whereas this was true for the elbow and ankle in the southern African black individuals. This study indicated moderate impacts in transferring (53%), walking (51%), and eating (41%) activities for all individuals. Females presented with significantly higher ADLs for all activities except posture changes whereas problems with eating and talking were more often seen in southern African white individuals. Differences between different socio-economic status groups were also noticed with the lower

SES group showing increased levels of impairment across most of the ADLs which may relate to activity differences when age is controlled for.

The focus of this research was to provide deeper information into impairment and disability caused by DJD. To conduct research on individuals where their lives and stories were limited and underexplored. This research highlights the need to continue studies on skeletal remains of individuals impaired by DJD, with focus on trends on joint and activity limitations within past and present contexts.

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1. INTRODUCTION

Disability is often used as a broad umbrella term, branching through physical, sensory, learning, and mental impairments. As such, a single definition of disability may be complex to narrowly define. Leonardi *et al.* (2006) state that for a definition to be reliable it must apply to all disabled people, without creating subgroups such as wheelchair users, autistic individuals, hard of hearing and so on. It should account for all types of severity, and highlight the environmental effects, whilst not focusing too intently on the causes of disability. The significance of having a clear definition is vital for the various role-players - such as lawyers, policymakers, government, and most importantly researchers - to ensure they understand how best to serve this community.

Over 15% of the world population is currently considered, by the WHO, to be disabled – translating to over 1 billion individuals (WHO, 2011). Most people may experience some form of disability throughout their lives, albeit for a short period or as they age (WHO, 2011), as this research will show. According to Iezzoni and colleagues (2014), it is important to begin intently focusing on something that affects so many individuals and to provide better services now, placing their well-being at the forefront as numbers begin to increase in the years that follow.

The WHO's (2007) international classification of functioning disability and health (ICF) has attempted to provide a fully conceptualised definition which is important in this study. Their definition frames disability as the negative interaction between an individual, with any form of health condition that implicates the individual's personal and environmental factors (WHO, 2007). What this, and most other definitions often leave out, is the *individual's* experience of disability and/or the intersectionality of being human. This often results in a lack of data on the individual's well-being, quality, and satisfaction with life (Leonardi *et al.*, 2006). There is a growing need for definitions to incorporate individual contexts within different countries and how this impacts the disabled experience.

Disability exists on a spectrum, the boundaries and lines become difficult to accurately define when there is so much variability found among people and populations (Shakespeare, 2018). Fundamentally, even if there was a definition that was able to capture every disabled experience, from across every culture across the globe, people still may or may not choose to identify as being disabled for a variety of personal reasons. Watson (2002) debates this when

discussing the challenges around the self-identification of the disabled category, where many individuals choose not to place their disability as a defining factor of their identity. The identity of the individual, and the context they are in, provide one example of the intersectionality that takes place in the world of understanding disability.

Within the South African context, Stats SA (2011) reported that 7.5% of their population (older than 5 years) presented with some form of physical disability. According to Stats SA (2011), the demographics of the South African disabled population group indicate that females are more frequently reported to have a physical disability at 8.5%, and this is slightly lower in males at 6.5%. Black South Africans have the highest disability rate (7.8%), followed by White South Africans (6.8%) and then South African Indians and Coloureds, both at 6.5%, respectively. Age-related disabilities vastly increase from the age of 50 years, with just over 1 in 10 people (12.2%) reporting having a physical disability at this age. This proportion drastically increases to over half (53.2%) for individuals aged 80 years and older (Stats SA, 2011). This information offers staggering data on the severity of disability across the country, but most importantly in older age which needs to be prioritised.

1.1. Necessity of Research

Research on disability has covered substantial ground in recent years (Shakespeare, 2015); however, there is still so much to learn in a vast variety of disciplines, including forensic anthropology and bioarchaeology. The medical/clinical and social models discussed in this chapter provide information that is essential to understanding the effects of disability. Neither model fully encapsulates what disability represents today. While there have been attempts to create new or hybrid models (Marks, 1997; Llewellyn & Hogan, 2000), these still have a far way to go in terms of their inclusion in skeletal analysis. Even more so when turning to fields of forensic anthropology and bioarchaeology, the former of which has shown very little research in describing disability, although discussions have been had around the topic (Cox & Mays, 2000; Burt *et al.*, 2013). Bioarchaeological approaches, such as the Index of Care (Tilley & Cameron, 2014), combining physical skeletal manifestations of pathology and trauma and interpreting these within individuals' social contexts have done much to enable a more holistic understanding of past human life experiences when it comes to injury and disease. In a modern setting, assessing at a hybrid model including information garnered from both medical and social sources, related to patient experiences, of information can do much to better understanding inherently complex topics such as disability.

Research to date on Degenerative Joint Disease (DJD) has primarily focused on clinical settings, often with the use of epidemiology, surgical interventions, and the aetiology around the disease (Altman *et al.*, 1995; Weiss & Jurmain, 2007; Loeser *et al.*, 2012; Litwic *et al.*, 2013). Studies of DJD on skeletal populations are mainly representative of historical and prehistorical societies (Steckel *et al.*, 2002a; Lieverse *et al.*, 2007; Klaus *et al.*, 2009). This is problematic when assessing at modern, region-specific populations, according to Fransen *et al.* (2011), when conducting studies, it is vital to determine the context-specific prevalence rates and risk factor profiles within a specific group of individuals to provide a well-rounded understanding of DJD in these areas. A study conducted by Usenbo *et al.* (2015) indicated that there is a major lack of information in South Africa regarding DJD studies. This meta-analysis indicates that over 35 years, beginning in 1980, there have only been 5 studies dedicated to DJD. This excludes studies within recent years, which were expected to increase these numbers. Nevertheless, it still indicates a research gap that has not been extensively pursued.

In South Africa, there are known imbalances between different societal groups and their access to healthcare given their socioeconomic status (Benatar, 2013; Young, 2016; Maphumulo & Bhengu, 2019). Disabled individuals are typically more marginalised, poorer and older, which all feeds into the increasing risk factors for substandard health (Kuperi & Hanass-Hancock, 2020). Specifically, a distinct correlation between barriers to healthcare access and age plays a significant role, with older individuals often not having sufficient funds or transportation to seek assistance (Henning-Smith *et al.*, 2016; Vergunst *et al.*, 2017). There is a need for research to aid in identifying these nuances, especially between different socio-economic groups, to identify the extent and severity of disability through life and death. As well as a need to implement the outcomes of this research to have a larger effect on the broader community. This present study aims to address these issues in a modern South African skeletal collection population.

Researchers have estimated that by 2050, 1.6 billion of the population will be over 65 due to an increase in the average individual's lifespan and with it will likely be an increase in DJD (Song *et al.*, 2020). It is important to understand and conduct as much research on these individuals now, for society to be better equipped for them in the future. An additional concern is that to date, there is no treatment to cure or prevent possible DJD (Buckwalter *et*

al., 2004). It has been clearly understood as a progressive disease and if there are no preventative measures to halt the decline, it will continue to progress at a constant rate (Waldron, 2009). As individuals are living longer, the disease is likely to affect a growing number of individuals worldwide – rendering the notion that studies around DJD should be of increasing priority.

As can be seen, there is a complex link between DJD and population-specific studies, it is multifactorial and multi-layered, which has glaring repercussions for these individuals in all scopes of their lives. People living with disabilities often do not have equal access to healthcare, equality and face lower rates of quality of life (McMahon & Shaw, 2005; WHO, 2011; Maart & Jelsma, 2013; Meade *et al.*, 2014; Santuzzi & Waltz, 2016). This is in addition to experiencing exclusion from everyday life activities, only adding to the rejection faced by the society around them (Jespersen *et al.*, 2018).

While bioarchaeological approaches making use of the Index of Care (Tilley & Cameron, 2014) are typically implemented on historical populations, the present study aims to adapt and modify it to a modern South African context to enable a more holistic approach to understanding the effects DJD may have on a person's daily activities of living, and therefore quality of life. There are limits to relying solely on a medical perspective or a social perspective when understanding disability, especially in South Africa. Taking a bioarchaeological approach will allow for a clinical approach that also accounts for social influences. The incorporation of bioarchaeological methods will allow for aspects of the lived experience of those with a disability to be inferred. This is vital for South African contexts where particularly detailed information, such as medical records, cannot be obtained and where social disparities result in very different lived experiences. This study has therefore attempted to create a model to bridge the gap between the medical and social perspectives of studying disability (specifically due to senescence) in a modern South African skeletal collection. Allowing for a more well-rounded understanding of the deceased's lived experience and their life as a disabled individual through their skeletal biomarkers.

2. AIM AND OBJECTIVES

This research was aimed at developing a new method to assess disability caused by degenerative joint disease in a southern African adult skeletal sample.

The objectives for this research were as follows:

1. Develop a new scoring system to assess the degree of degenerative joint disease in various axial and peripheral joint regions.
2. Test the intra- and inter-repeatability of the newly developed scoring system on a portion of the original sample.
3. Using the newly developed scoring system, document the extent and severity of degenerative joint disease in the sample.
4. Determine the level of impairment in each of the proposed Activities of Daily Living (ADL), as these relate to specific joint regions, using the newly developed scoring system.
5. Explore any possible trends in disability as seen in different socio-economic contexts between DJD and ADLs in the sample.

3. LITERATURE REVIEW

3.1. *Models of Disability*

The study of disability is often divided into two distinct approaches, these being either medical/clinical or social (Byrnes & Muller, 2017). The former was created during the Industrial Revolution (Davis, 2013), where it is often understood as a form of dysfunction that the individual carries. These can be long- or short-term, from birth or acquired during life and can be aesthetic or functionally inhibiting (Byrnes & Muller, 2017). Since this model borrows its foundation from the disease model, it has become problematic because there is often a strong, inseparable correlation between disability and illness/disease (Retief & Letsosa, 2018). Many disabled individuals are not sick with daily health problems, but rather an ongoing impairment (Llewellyn *et al.*, 2008). Nevertheless, they are often lumped together because both emphasise practitioners as those who identify a condition and prescribe treatment to correct any abnormalities (Llewellyn & Hogan, 2000).

Within medical research, approaches to identifying disability often use the World Health Organisation (WHO) International Classification of Functioning, Disability and Health (ICF) as a guideline (WHO, 2003). The ICF lists various functionalities with descriptions attached that the researcher then uses to compare likely impairment. Goodley (2014) and Hammell (2004) have deeply criticised this method, stating that it overlooks so much around the specifics of disability. They and others suggest that while this approach is excellent when the researcher is attempting to classify impairment, it cannot and should not go beyond this motive (Shuttleworth & Meekosha, 2017).

One of the shortcomings of this model is that it fails to take any form of context into account (Areheart, 2008; Goering, 2015). The individual has been socialised that they require fixing and will therefore attempt to try correcting their disabilities to conform with societal needs. Implicitly, individuals with limited-to-no access to healthcare or medical resources may find it significantly more difficult to gain access to the world because they have no way of adapting to societal needs (Vergunst *et al.*, 2017; Mutwali & Ross, 2019). This system is deeply flawed in its ideology as not every disability can be treated and not all have equal access to the care they require.

Conversely, the social model of disability is not simply limited to mental or physical impairments, but it sees the society as a whole that needs to be fixed. This model was

constructed in the 1970s, from the Fundamental Principles of Disability document and later reviewed by sociologist Mike Oliver (UPIAS, 1976; Oliver, 1990). It postulates the difference between disability and impairment, and for the current research study, this distinction needs to be clearly understood. Impairment is a lack of functioning within the physical body, this can be the loss of a limb as an example (Retief & Letsosa, 2018). Whereas disability is a disadvantage leading to the restriction of normative activities; this can be the lack of ramps into a particular building (UPIAS, 1976). What then follows from this limitation is considered to be social and/or economic exclusion from daily life.

The social model prioritises disability and focuses on society's incapacity to provide disabled individuals with adequate resources. While impairment is a significant aspect of the disabled experience, different contexts would be considered more disabling than others. The social model of disability simply cannot be limited to mental or physical impairments, rather it must be viewed as a social construct (Byrnes & Muller, 2017). There are significant shortcomings in this model of thinking about disability (Marks, 1997). Debates have often centred around the model being too simplistic in its categorisations. For example, Retief and Letsosa (2018) argue that the lines between where disability ends, and impairment begins are significantly harder to distinguish. Other researchers have criticized the social model heavily as it often completely disregards the physical impairment that the individual lives with (Beaudry, 2016). This overlooking of the lived experience of the individual living with the impairment is fundamentally problematic as it neglects their daily activity in everyday life (Llewellyn & Hogan, 2000; Anastasiou & Kauffman, 2013).

The social model of disability simply cannot be limited to societal norms and viewpoints, and while it focuses on interactions within society, it must include the one the individual has with themselves (Byrnes & Muller, 2017). Similarly, while impairment is a significant aspect of the disabled experience, different individual contexts would be considered more disabling than others. With this information, researchers are now turning to hybrid models that include the fundamental principles of the medical/clinical and social models, but most importantly, attempt to incorporate the individual experience (Marks, 1997; Llewellyn & Hogan, 2000). Other researchers are attempting to identify alternative models that could be used independently or in conjunction with those already in existence (Haeghele & Hodge, 2016; Berghs, 2017; Retief & Letsosa, 2018).

3.2. *Approaches to Disability*

One discipline, that has attempted to take on a dual approach to understanding the effects of disease and care (with links to impairment and disability) on individual lived experiences, is bioarchaeology. Research in this discipline has attempted to recreate the social component of life in the past, often inferred using external information, such as gravesites and knowledge of mortuaries and other social practices (Cross, 1999; Roberts, 1999; Shakespeare, 1999). According to Tilley (2015), the definition of disability within this discipline should always be contextual and situational, as it is given meaning by the individual *and* the community. In addition, skeletal remains can be a wealth of knowledge concerning diet, diseases and health, physiological stress, violence, and trauma; often leading to an understanding of the societal history at that particular time (Larsen, 2002).

Examples of the understanding of disability within bioarchaeology can be seen throughout history. Records thus far indicate cases where individuals have suffered from extreme and severe impairment, due to disease or trauma, and being able to live with such for extended periods (Dickel & Doran, 1989; Hawkey, 1998; Luna *et al.*, 2008; Oxenham *et al.*, 2009). Lovell (2016) describes an archaeological case in ancient Roman times where a male individual suffered a fracture to his femoral head, ultimately shortening his leg, and leaving him visibly impaired. This study also looks at how the individual lived with this impairment and how these results were interpreted. Inferences were based on the individual's ability to adapt to their environment and receive long-term care after the injury (Lovell, 2016). Other studies of the prehistoric period such as Shanidar 1 (Kent, 2016), “Old Man” La Chapelle-aux-Saints (Haeusler *et al.*, 2019), and TB1 (Maloney *et al.*, 2022) follow this same pattern. The bridge between the impairment and how the individual was disabled by the impairment is very much inference-based across the literature.

Identifying and quantifying care within health indices has been of significant research in bioarchaeology as it bridges the gaps between the society and medicine (Steckel *et al.*, 2002b; Paine *et al.*, 2009). The first rendition of such a model was proposed by Tilley & Oxenham (2011), which attempts to identify the social components and how this was aided through the fulfilment of the needs of the disabled individual. One of the most valuable examples of this is seen in the “Index of Care” (IC), used in identifying and interpreting health-related care within a society, specifically in an archaeological context (Tilley & Cameron, 2014). Additional indices were then created to test the frailty standards among

differing populations (Goodman & Martin, 2002; Steckel *et al.*, 2002b; Zedda *et al.*, 2021). The most considerable and comprehensive of these is the skeletal frailty indices (SFI), which will be discussed below (Marklein *et al.*, 2016).

3.3. *Index of Care*

The Index of Care (IC) model is based on the bioarchaeology of care model originally constructed by Tilley (2012). The latter is the first of its kind about identifying the necessity of care, both for the individual and in the communal context (Tilley, 2012). Both are primarily comprised of four sections; however, the IC follows a more critical and thorough model, providing clear guidelines on how to conduct a care-based analysis (Tilley & Cameron, 2014). Care, in this context, is defined as the provision of assistance to a person experiencing a particular disability and thus caregiving is generally inclusive of a third party providing the care needed to live (Tilley & Cameron, 2014). The first section documents aspects related to the individual's osteobiological profile, pathology and injuries related to the body. The second section establishes the impact of the disability, by considering likely clinical complications of observed pathology and its impact on functionality (e.g., the ability to complete daily tasks). For this identification method, the model uses conditions identified by the WHO ICF (WHO, 2003). The third section attempts to identify the characteristics of care likely needed, within the context of the associated functional impact, within the individual's socioeconomic and environmental contexts. The final section allows for the interpretation of the model by exploring the societal relations of how the community would aid in assisting this individual. The model then takes all the information gathered, combined with the researchers' knowledge and previous literature to draw reasonable conclusions about the severity of disability and the need for care (Tilley & Cameron, 2014).

This index highlights the significance of building up realistic narratives of how the individual and the society around them may have perceived disabilities (Tilley & Cameron, 2014). This model is not designed to produce precise answers surrounding disability and care in the past; however, it does provide a great deal of insight that has been lacking until recent years. It is only by placing value on the individual *and* the context that they lived in that greater strides in comprehending the nexus of disability can be achieved. The idea that one can create a model, based on skeletal remains and their surrounding context, to aid in identifying the disability an individual encountered, is significant for this study.

3.4. Skeletal Frailty Index

In addition to the IC model, the skeletal frailty index (SFI) has also been proposed as a methodological approach to studying the relationship between stress and health, with specificity on frailty (Marklein *et al.*, 2016). This index creates a substantial link between biological anthropology when studying frailty and health in the living, as well as in bioarchaeology when determining health and frailty from skeletal markers (Marklein *et al.*, 2016). The model indicates that lifelong stress would have a substantial impact on physiological health, morbidity, and mortality (Goodman & Leatherman, 1998; McEwen & Seeman, 1999). Created to identify and measure the changes and severity of frailty between different population groups, this was done by gathering a vast amount of information on various pathologies which are linked to frailty and scored based on multiple biomarkers of stress/frailty from existing models (Marklein *et al.*, 2016). The biomarkers were then given a score of present or absent for each stress-related disease/disability found in the individual. The quantification of this information would provide the researcher with a value that is known as the SFI, which could be tested against populations to identify frailty scores between them.

3.5. Senescence

Degenerative joint disease (DJD) is the focus of the present study. DJD is known to be the leading cause of disability in adult and older populations (Dunlop *et al.*, 1997; Sharma *et al.*, 2001; Covinsky, 2006; Covinsky *et al.*, 2008). These older populations will be termed senescent individuals for this study, as DJD is regarded as a senescent disease resulting in increased deterioration of bony structures, specifically joints. Senescence can be broadly understood as the (1) general impairment of bodily functions, (2) a decreased ability to handle physiological stressors, (3) an increased risk of acquiring age-related diseases, as well as (4) a greater likelihood of death (Kirkwood, 1996: 1009). The premise is that, over time, organisms undergo physiological deterioration that leads to an increase in vulnerability to stress and thus increases the probability of death (Cristofalo *et al.*, 1999). These often manifest through the ceasing of cell, organ, and somatic growth (Song *et al.*, 2020). This is observed within the skeletal system as changes in bone mineral density, and macro- and microarchitecture because of disruption in normal bone homeostasis (Manolagas & Parfitt, 2010; Farr & Khosla, 2015 Farr *et al.*, 2016; Pignolo *et al.*, 2021).

Not all individuals will begin the process of senescence at the same point in time. Additional aspects such as variations in genetics, physiological stress, overall health, daily activities, and other comorbid disabilities play an equal factor (Crews, 2003; Crews, 2007). A large body of research exists on a host of degenerative diseases with visible biomarkers used for age estimation and general health assessments; for example, the effects of osteopenia and osteoporosis (e.g., Mays, 1999; Siris *et al.*, 2001; Mays *et al.*, 2006), osteoarthritis (e.g., Waldron, 2009), intervertebral disc disease (e.g., Roberts *et al.*, 2006), and pathological trauma (e.g., Friedman & McEwen, 2004).

Degenerative joint disease is a highly common joint disease, which is typically associated with the elderly and is present in more than 50% of people over 60 years of age (Martin & Buckwalter, 2002; Price *et al.*, 2002; Ortner, 2003). Researchers have estimated that by 2050, 1.6 billion of the world's population will be over 65 due to an increase in an individual's lifespan and with it will likely be at an increased risk of developing DJD (Song *et al.*, 2020). With older, disabled individuals taking up a larger portion of the world population, it will become vital for research to start identifying the root causes of why these diseases occur and how they may affect daily life, the latter of which will be the focus of this study.

3.6. Degenerative Joint Disease

Degenerative joint disease has been known to include additional pathologies with similar appearances, such as Osteoarthritis (OA), intervertebral disc disease (IVDD), rotator cuff disease, spondylosis, rheumatoid arthritis, and diffuse idiopathic skeletal hyperostosis (DISH) (Waldron, 2019). For this research, osteoarthritis, IVDD, spondylosis and DISH have been classified as DJD. Osteoarthritis is primarily defined as the breakdown in the integrity of the articular cartilage due to wear and tear (Sarzi-Puttini *et al.*, 2005). Two types of osteoarthritis will form the basis of this research, the first being idiopathic, primary osteoarthritis which has recently been identified as having an inflammatory component (Doherty *et al.*, 1983; Sanchez-Lopez *et al.*, 2022). Secondary osteoarthritis is mostly due to a post-traumatic factor, potentially from a prior injury to the articular surface (Doherty *et al.*, 1983; Coryell *et al.*, 2021). The latter will be the main focus of this research.

There are various types of joints present in the body each with its own specific function. Immobile fibrous (synarthroses) joints have little to no impact on movement, an example of this type of joint is sutures in the skull (Drake *et al.*, 2020). For this study joints that have

little movement (amphiarthrosis), which are also described as cartilaginous joints, were used. A clear example of this type of joint is between two vertebral bodies, there is an intervertebral disc that allows for axial movement (Drake *et al.*, 2020). Those that have full movement (diarthrosis or synovial) were also included in this study, these joints are understood to be encased in a synovial membrane and the joint cavity within (Drake *et al.*, 2020). Synovial joints can be divided into six distinct types, these are ball and socket, hinge, condyloid, pivot, gliding and saddle joints (Drake *et al.*, 2020).

In a joint without DJD, the articular cartilage is smooth, compressible, and well-lubricated, allowing for the protection of the underlying bone during joint loading, ultimately preventing damage to occur (Wang *et al.*, 2011). In addition, the presence of chondrocyte cells produces and maintains the cartilage found at a particular site through the delicate balance of various components, such as collagens, proteoglycans, and non-cartilaginous proteins (Buckwalter *et al.*, 2005). Each joint requires constant replacement of these components; however, in older age changes to these cells may inhibit the maintenance and restoration of the tissue (Buckwalter *et al.*, 2005). In DJD susceptible joints a decrease in water in the proteoglycan content makes the cartilage more fragile and susceptible to mechanical wear and tear over time (Waldron, 2009). Once this process begins fissures within the bone underlying the cartilage may form, in order to regain stability, the joint begins responding with new bone formation (Buckwalter *et al.*, 2004; Waldron, 2009). This often leads to major clinical features including pain, mobility loss and/or joint stiffness - which are often progressive (Bijlsma *et al.*, 2011).

Degenerative joint disease is often a result of repetitive motions and old age (Aufderheide & Rodriques-Martin 1998; Marklein *et al.*, 2016). Upon characterising it, a few key processes can be observed, namely, the loss of articular cartilage at a specific location, often associated with marginal and subchondral bone changes of all joints associated with direct interosseous contact (Rogers *et al.*, 2004). These can manifest as a variety of biomarkers, such as eburnation, porosity, osteophytes,, and contour changes (Rogers *et al.*, 1987). These biomarkers of DJD can present a range of clinical manifestations, from slight pain to complete immobility of motion (Swagerty & Hellinger, 2001).

3.6.1. Eburnation

Eburnation is the result of long periods of bone-on-bone contact (Molnar *et al.*, 2011). The space lost between two joints, with the destruction of the articular cartilage, means that the joint will encounter significant friction, leading to a polished effect after a significant period (Rothschild, 1997). Therefore, when discussing joint disease, eburnation is the most significant indication due to the understanding that complete joint failure has occurred (Molnar *et al.*, 2011).

3.6.2. Porosity

Porosity often manifests when there is a discontinuation or reabsorption of subchondral bone, induced by osteoclast activity (Rothschild, 1997; Botter *et al.*, 2011). This is often noted in the earlier stages of degeneration, where there is a thinning of the plate and increased porosity, leading to an overall decrease in bone density (Li *et al.*, 2013). Whilst there appears to be a definitive link between osteoporosis and osteoarthritis, this process is still poorly understood (Stewart *et al.*, 1999).

3.6.3. Contour Changes

After significant osteoclast activity, resulting in destabilisation, repair of the bone is needed and therefore osteoblast activity is increased (Botter *et al.*, 2011). This, combined with constant mechanical loading, has a significant impact on the density of the underlying bone, with the subchondral bone plate often turning sclerotic as a result (Li *et al.*, 1999). This modelling process of the joint structure is a mechanism that adds bone tissue to the existing surfaces (Goldring & Goldring, 2010).

3.6.4. Osteophyte

Osteophytes or bone spurs, follow a similar process to the contour changes. They are osseocartilaginous metaplastic tissues which often form at the margins of synovial joints as a result of degeneration (Gelse *et al.*, 2003). They are considered to form as a result of abnormal stress on the joint margin, as degeneration occurs (Rogers *et al.*, 1997). This differs from enthesophytes which are spurs that occur where the ligament attaches to the surrounding bone and begins to ossify – both pathologies can be seen in osteoarthritis and DISH (Hardcastle *et al.*, 2014). Enthesophytes are believed to form as a response to seronegative spondyloarthropathies and tend to extend in the same direction as the ligament (Rogers *et al.*, 1997). In cases where lipping is involved but is restricted to the vertebral body, this is then

referred to as osteophytosis (Armstrong, 1968). Differentiating between the two types of bone formations, especially in their beginning stages, may be extremely difficult and as such have been often grouped.

Intervertebral disc disease and/or spondylosis, both occur in the vertebrae, as a result of degenerative progressive structural failure often due to age-related, genetic, occupational and environmental factors (McCormack & Weinstein, 1996; Adams & Roughley, 2006; Shankar *et al.*, 2009). If left untreated both can lead to pain, impairment, and significant disability in later life (Shankar *et al.*, 2009; Ferrara, 2012). The pathophysiology of both diseases is noted as progressive structural changes within the vertebral disc and its substructure, often leading to the disintegration of the vertebral endplate and desiccation of the nucleus (Kumaresan *et al.*, 2001; Shankar *et al.*, 2009). This will progress with severe damage to the vertebral disc, with osteophyte formation as a result (Kumaresan *et al.*, 2001; Ferrara, 2012).

Lastly, DISH or Diffuse Idiopathic Skeletal Hyperostosis is known as the ossification of tendons and/or ligaments (known as enthesophytes) – primarily on the anterior aspect of the spine (Mader *et al.*, 2013). New bone formation of cancellous and cortical bone is formed, suggesting ongoing bone remodelling (Kuperus *et al.*, 2020). Whilst common in the spine, it has also been observed throughout the body, exclusively at the entheses of joints (Holgate & Steyn, 2016). To date no known aetiology has been identified, correlations between the environment, genetics, obesity, and diabetes amongst others, have been suggested to lead to DISH (Kiss *et al.*, 2002; Mader *et al.*, 2013). DISH has been known to occur in older male individuals, generally over 40 years old, and has similar limiting pathology leading to disability (Utsinger, 1985). Increased pain and mobility loss have been noted to occur mostly at the thoracic vertebrae but have been seen throughout the spine and peripheral skeleton (Rogers & Waldron, 2001). Spinal stenosis, or the impingement of nerves in the vertebral column, is present in cases of DISH (Mader *et al.*, 2013). Another comorbidity found alongside DISH is that of osteoarthritis, often due to the similar pathologies seen between the two making it difficult to distinguish between the two (Rogers & Waldron, 2001).

3.7. DJD within South Africa

There has been very little research conducted in South Africa with regards to DJD, and significantly fewer on creating a full skeletal scoring system for this population. What is seen in the literature is a study by Van Der Merwe *et al.* (2006) which centred on DJD studies

around scoring vertebral osteophytes and attempted to provide demographic information about the changes seen between populations. Their study highlighted that black males were significantly more prone to DJD changes as opposed to their black female counterparts. Similar studies were conducted years prior by Taitz (1999), who concluded that black individuals suffered fewer degenerative changes than their white associates. However, this study was restricted to the cervical vertebrae with osteophytic growth being the main determinant of degeneration. Other studies have provided insightful information regarding DJD and its relationship with the context of archaeological time-periods and differences in lifestyles (e.g., L'Abbé & Steyn, 2007; Landsman *et al.*, 2022). To date, there have been no South African studies around DJD and its link to disability based on skeletal remains.

3.8. Limited Functioning Related to DJD

The information below is a summary of bony joint regions, clinical limitations, and impairments thereof, concerning where DJD is present within a specific joint. The joints that will be observed are the temporomandibular region (TMJ), the upper peripheral region (including the shoulder, elbow, wrist, and finger joints), the lower peripheral region (including the hip, knee, ankle, and toe joints) and the axial region (including the cervical, thoracic and lumbar vertebral joints). These upper and lower peripheral joints are all synovial joints consisting of a layer of hyaline cartilage (except the TMJ), and joint capsules consisting of an inner synovial membrane and outer fibrous membrane (Drake *et al.*, 2020). They are typically classified according to the shape of the articular surface and the associated movement this surface allows (Drake *et al.*, 2020). Over time and with the aging process, these joints will become more fragile and susceptible to mechanical changes (Drake *et al.*, 2020). The joint will encounter bony changes and the progression of this will eventually lead to the impediment of specific movements within the joint (Drake *et al.*, 2020).

3.8.1. Temporomandibular Joint

This is noted as a peripheral joint and is located between the left and right condyles of the mandible and the mandibular fossa and articular tubercle on the temporal bone (Drake *et al.*, 2020). The TMJ is a hinge and sliding joint that allows depression and elevation, and protrusion and retraction of the jaw (Drake *et al.*, 2020). Unlike other synovial joints the TMJ is covered by a layer of fibrocartilage and completely separated by a fibrous articular disc (Drake *et al.*, 2020). TMJ DJD is often considered to occur as a result of internal derangement of this disc (Dimitroulis, 2004). Typically, eburnation is not seen in this joint;

however, traits such as porosity, joint contour changes and osteophyte formation on the periphery of the joints are indicative of DJD progression (Rando & Waldron, 2012). Causes have been noted as excessive mechanical stress, including severe malocclusion, skeletal jaw asymmetry, and muscle overuse (Wang *et al.*, 2015). This joint is susceptible to pain, and limited ranges of movement (including rotations and anterior translation) where DJD is present (Emsoff & Rudisch, 2003; Ibi, 2019). Due to this, and its near continuous use, it is often seen that these individuals may suffer when attempting activities such as eating, drinking, and speaking (Rando & Waldron, 2012; Alakailly *et al.*, 2017).

3.8.2. Shoulder Joint

The shoulder joint consists of several articular surfaces between the humerus, scapula, sternum and clavicle, known as the sternoclavicular, acromioclavicular and the glenohumeral joints (Drake *et al.*, 2020). The glenohumeral joint will be the focus here and is identified as a synovial ball and socket articulation (Drake *et al.*, 2020). It is multiaxial, providing a large range of movements (Drake *et al.*, 2020). The joint lacks stability due to the wide range of movements and this is supplemented by the rotator cuff muscles, biceps brachii and the extracapsular ligaments (Drake *et al.*, 2020). The occurrence of DJD in the glenohumeral head is uncommon unless there has been local trauma to the site and secondary DJD as a resulting factor (Waldron, 2009). Eburnation is typically found on the humeral head, and a rim of osteophytic lipping is generally seen on the glenoid (Waldron, 2009). The joint is prone to pain and movement limitations (specifically in external rotation and abduction) where DJD is present (Chillemi & Franceschini, 2013). This can have implications when lifting heavy objects is needed (including transferring oneself from one position to another), as well as eating and bathing (Millett *et al.*, 2008).

3.8.3. Elbow Joint

This joint is made up of several joint surfaces associated with the upper peripheral skeleton and includes the humerus, ulna, and radius (Drake *et al.*, 2020). The humeroulnar and humeroradial joints are known to be a synovial hinge joint, whereas the radioulnar joint is understood as a pivot joint allowing for pronation and supination (Drake *et al.*, 2020). According to Waldron (2009), trauma is a significant influencer of DJD over the typical arthritic degeneration of the joint. Where DJD occurs in the absence of trauma it has been known to occur at the humeroulnar joint later in the life of individuals (Gramstad & Galatz, 2006). Studies have indicated that the primary characteristic of DJD in this joint are related

significantly to osteophyte formation on the articular surface peripheries and not the articular surface itself (Chueng *et al.*, 2008; Lim *et al.*, 2008). Here again, it is noted that pain and limitations in movement regarding flexion and extension of the elbow joint are concerned (Doherty & Preston, 1989). This would limit any activities involving flexion and extension, which would be important for transferring from one location to another and eating (Kozak *et al.*, 1998; Ravalli *et al.*, 2019).

3.8.4. Wrist Joint

This joint is made up of several joint surfaces within the upper peripheral joint and includes the distal ulna and radius, with all carpal and proximal metacarpal joints (Drake *et al.*, 2020). This is divided into articulations with the radius and carpals, intercarpal, as well as distal radioulnar joint (DRUJ) (Drake *et al.*, 2020). The radius and carpal joint is defined as a condyloid (modified ball and socket joint) synovial joint with a convex contour on the carpal surface and a concave radial surface (Drake *et al.*, 2020). DJD often occurs in the radial aspect of this joint and is seen commonly in the lunate and scaphoid carpal bones (Waldron, 2009). The former includes clinical manifestations of this joint, which include pain and movement limitations, specifically with ulnar wrist flexion (ulnar deviation) and radial wrist extension (radial deviation) (Weiss & Rodner, 2007). These are most prominent in activities surrounding drinking and object manipulation, research has noted that the wrist has less significant degrees of DJD when compared to other upper peripheral joints (Adams *et al.*, 2003; Laulan *et al.*, 2015).

3.8.5. Finger Joints

This joint is made up of several joint surfaces within the upper peripheral joint and includes the distal metacarpals as well as all proximal phalanges within the hand (Drake *et al.*, 2020). All of these joints are known as condyloid synovial joints, which allow for extension, flexion, adduction, abduction, circumduction and limited rotation (Drake *et al.*, 2020). This occurrence is often secondary to trauma and is known to occur in the thumb base and metacarpophalangeal joints (Waldron, 2009). Manifestations, where DJD is present, can lead to a decrease in grip or pinch strength, often due to movement limitations noted, as well as pain that is associated with this impairment (Domett *et al.*, 2017). These manifestations can lead to limitations in activities such as eating and object manipulation (Buchanan & Kean, 2002).

Hand osteoarthritis presents itself in a variety of ways, some of which are Bouchard and Heberden nodes - this can present as generalised or at the base of the thumb joint (Kalichman & Hernández-Molina, 2010). Bouchard and Heberden nodes are noted as bony enlargements of the proximal interphalangeal joint and distal interphalangeal joint, respectively, with both affecting structural abnormalities (Kloppenburger & Kwok, 2012).

3.8.6. Hip Joints

This joint is made up of several joint surfaces within the lower peripheral joint and includes the femur and pelvis, and sacrum (Drake *et al.*, 2020). This is divided into two joints, in particular the sacroiliac and femoroacetabular joints (Drake *et al.*, 2020). The latter is defined as a synovial ball and socket joint, much like the shoulder (Drake *et al.*, 2020). The femoroacetabular joint is designed for weight-bearing and stability, when impaired it sacrifices on mobility due to the complete encapsulation of the femoral head by the acetabulum in its articulation (Drake *et al.*, 2020). There are manifestations regarding limitations in movement (specifically when internal and external rotation is concerned), as well as significant pain in this region with DJD (Domett *et al.*, 2017). Occurrences of DJD in this region may be due to slipped capital femoral epiphysis, acetabular protrusion, and congenital hip dislocation (Waldron, 2009). The implications of this may lead to limitations in walking and/or sitting/squatting (Cibulka *et al.*, 2009; Buchanan & Kean, 2002).

3.8.7. Knee Joint

This joint is made up of several joint surfaces within the lower peripheral joint and includes the femur, tibia, and patella (Drake *et al.*, 2020). The femur and tibia articulation is the largest synovial joint in the body, and is known as a modified hinge joint (Drake *et al.*, 2020). Between the two articular surfaces, are two C-shaped fibrocartilaginous cartilages, which assist in accommodating in weight-bearing and changes of shape during joint movements (Drake *et al.*, 2020). DJD in this joint is often prone to develop in response to obesity, however activity-related injuries and subsequent degeneration of the joint surface are also common causes of knee DJD (Coggon *et al.*, 2001). The clinical implications are often noted as movement limitations in flexion and extension, and pain in this joint is of concern when DJD is present (Domett *et al.*, 2017). Other manifestations include surrounding muscle weakness, accompanied by lateral instability, which is often vital for activities such as walking and squatting (Buchanan & Kean, 2002; Bobes Álvarez *et al.*, 2021).

3.8.8. Ankle Joint

This joint is made up of several joint surfaces within the lower peripheral joint and includes the tibia, fibula (Drake *et al.*, 2020). It is known to be a synovial hinge joint, with the tibia and fibula providing a deep socket for the talus to fit into (Drake *et al.*, 2020). Due to the shape of the talus with the posterior aspect being narrower than the anterior aspect, the joint is the most stable when the foot is dorsiflexed (Drake *et al.*, 2020). It is extremely uncommon for DJD to occur in the ankle, especially in the absence of trauma (Waldron, 2009). DJD of this joint is responsible for pain, and joint dysfunction and can often be limited in plantar flexion (the ability to point or flex one's toes downwards) (Van Valburg *et al.*, 1999). This can have a debilitating impact on the individual's ability to walk, thus affecting a seemingly major part of daily life (Queen, 2017).

3.8.9. Toe Joint

This joint is made up of several joint surfaces within the lower peripheral joint and includes the distal metatarsals and the 1st phalanx (Drake *et al.*, 2020). These joints are defined as condyloid synovial joints, with sphere-shaped heads of the metatarsals fitting into the phalanges (Drake *et al.*, 2020). DJD is nearly exclusively seen in the first metatarsophalangeal joint and only in the tarsal joints where trauma has occurred (Waldron, 2009). Where DJD is present there have often been impairments in locomotion (this is often found in the first metatarsophalangeal joint), and balance and pain when ambulation is taking place (Munteanu *et al.*, 2012; Roddy & Menz, 2018). This can often have implications for activities such as walking and balancing (Sinusas, 2012).

3.8.10. Axial Regions

All of the joints discussed in this study within the intervertebral joint, are known to be cartilaginous joints which offer limited and differing degrees of movement based on vertebral typology (Drake *et al.*, 2020). The spine as a whole faces many degenerative changes during the process of senescence. The main diseases that will be observed in this research are intervertebral disc degeneration, diffuse idiopathic skeletal hyperostosis and spondylitis. Gellhorn *et al.* (2013) state that it is significantly challenging to separate these diseases as the destruction of one will likely imply the other (Laplante & DePalma, 2012). Due to this reasoning, these aspects will be synonymous with each other; however, the criteria proposed by Kilgore (1985) will still need to be met regarding DJD.

In addition, stenosis of the spine should also be discussed herein. It is broadly defined as a narrowing of the central canal or intervertebral foramina (Atlas & Delitto, 2006; Melancia *et al.*, 2014). This is noted to have either unilateral or bilateral implications for impairment (Gellhorn *et al.*, 2013). Einstein (1977) conducted a study on lumbar stenosis for the same collection that will be used in this study, his findings dictate that degenerative changes were most likely to affect nerve roots. While it is challenging to determine the clinical manifestations of this disease, where degeneration and osteophytes are present at the nerve roots, stenosis will be considered to have played a role (Abbas *et al.*, 2010).

3.8.11. Cervical Vertebrae

Axial regions are often very challenging when identifying manifestations of DJD and subsequent limitations (Waldron, 2009). The cervical vertebrae are subdivided into the atlas, axis & C3-7 regions (Drake *et al.*, 2020). Where signs of DJD are present this can often lead to pain and limitations in the rotation of the neck motion, leading to limitations in an activity that involves a change in posture and head rotation (Özdemir *et al.*, 2001). Where stenosis is concerned, pain in the scapular, neck, upper back and general shoulder region may occur. In other circumstances, this may often impact motor or sensory loss in the upper regions of the body (Gellhorn *et al.*, 2013).

3.8.12. Thoracic Vertebrae

According to Waldron (2009), this section of the vertebra is one where there is little impact on overall functioning. While it is still possible to see implications where DJD is present, DISH is more commonly associated with the T1-12 regions (Laplante & DePalma, 2012). This can manifest as pain and movement limitations, especially when encountering activities that use axial rotation and lateral bending, leading to changes in posture (Hou *et al.*, 2016). Again, where stenosis is concerned, this may have a significant impact on the lower extremities, implicating both motor and sensory loss (Gellhorn *et al.*, 2013).

3.8.13. Lumbar Vertebrae

This is the last of the joints being considered for the axial regions (Drake *et al.*, 2020). These will be limited to the L1-5 and S1 bony regions of the spine. Where DJD has often been noted, this has led to an increase in pain and movement limitation in the lower back of the individual (Goode *et al.*, 2013). Which can then have implications on activities surrounding bending and flexibility when changing posture (Niosi & Oxland, 2004). Lastly, stenosis may

cause pain in the lower back, thigh, and gluteal regions, and can often include motor or sensory loss in these regions greatly affecting the lower limbs (Gellhorn *et al.*, 2013).

3.9. Implications on Quality of Life

Implications of DJD have been noted to be more commonly observed in the hand, knee, hip, spine, and foot (McDonough & Jette, 2010), and as osteophytosis in the vertebral column (Klaassen *et al.*, 2011). Studies in the past were mostly centred on knee and hip DJD, but recent studies have begun to look at other regions to expand on current knowledge (Creamer *et al.*, 2000; Salaffi *et al.*, 2005; Maly & Krupa, 2007). Corti & Rigon (2003) highlight risk factors that could increase the rate of DJD, such as occupation, physical activity related to the joint, genetic factors, biological sex, and joint injury (Sarzi-Puttini *et al.*, 2005). Comorbidity is seen in 67% of individuals with conditions such as peptic ulcers, strokes, hypertension, depression, and metabolic syndrome – although this is heavily under-researched (Swain *et al.*, 2020). Musculoskeletal comorbidities, often include trauma, tendon disorders, arthropathies and upper limb sprains (Kadam *et al.*, 2003). Kadam & Croft (2007) have stated that research suggests that comorbidity shows signs of increasing poor physical function of the individual and should require significant attention to reduce physical decline. Lastly, a relationship between muscle strength, ligament laxity and osteoarthritis has been found. What is seen is that a decrease in muscle strength can often lead to an increase in impairment, which includes pain, disability, and ability to perform ADLs (Steultjens *et al.*, 2001; Van der Esch *et al.*, 2006). These all feed into the growing need for an expansion of research in this field to better assist these individuals.

Studies have not just been done on pain and the lack of mobility, but also on psychological and secondary physiological impacts brought on by DJD. Osteoarthritis and related pain are regarded as one of the greatest motivators of psychological distress, alongside rheumatoid arthritis, and strokes (Penninx *et al.*, 1996). Other types of distress have been indicated as loneliness, anxiety, diminished self-worth, and depression – often leading to a reduced quality of life for these individuals (Litwic *et al.*, 2013; Sharma *et al.*, 2016). Physiologically, there has been information to support DJD and its relationships between obesity and helplessness, indicating a substantial need for assistance in both regards (Creamer *et al.*, 2000; Coggon *et al.*, 2001). The growing lack of self-efficacy has been known to lean into this perception of helplessness, which in turn leads to daily modifications or in some cases

may require the need for caregivers – both formal and informal (Creamer *et al.*, 1999; Gignac *et al.*, 2000; Allegrante & Marks, 2003).

3.10. *Activities of Daily Living*

It has been established that the clinical manifestations of DJD, regarding pain, stiffness, and swelling, can make it substantially difficult for individuals to perform Activities of Daily Living (ADLs) (Clynes *et al.*, 2019). The clinical understanding of ADLs is defined as a term that collectively describes the most basic, primary skills required for an individual to independently care for oneself (Edemekong *et al.*, 2021). A French nationwide survey of 10 000 individuals, showed that slightly over 80% reported limitations to daily activities (Fautrel *et al.*, 2004). Stamm *et al.* (2016) conducted a study to determine if individuals with osteoarthritis suffered from greater or the same level of ADL impairment as those without any DJD conditions. The study indicated that there was a significantly higher ADL limitation for those living with osteoarthritis (Stamm *et al.*, 2016). Other research has echoed similar results, specifically within the knee, with a definite link between DJD and ADLs limitations (Penninx *et al.*, 2001; Tamura *et al.*, 2016).

South Africa has conducted few studies into the limitations of ADL use in different communities. From the literature, most ADL studies are conducted in the same areas of Mpumalanga under the longitudinal study HAALSI (Payne *et al.*, 2017; Wang *et al.*, 2019; Harling *et al.*, 2020). These studies are insightful to rural contexts, but it is doubtful whether this could be directly applied throughout all areas in Southern Africa. Meanwhile, other studies have proposed a strong negative association between ADLs inability and the quality of life and/or depression (Phaswana-Mafuya *et al.*, 2013; Tomita & Burns, 2013; Yaya *et al.*, 2020). These studies attempt to quantify the number of ADLs and their relation to the individual's life, whereas this study will digest and understand which ADLs are most at risk.

Activities of daily living have become a reliable way of testing the functional status or level of impairment elderly individuals face (Hartigan, 2007). If an individual can complete more ADLs, they are seen as having an increased sense of independence within physical functioning (Milnac & Feng, 2016). According to Fusco *et al.* (2017), DJD is one of the most influential factors for an inability to perform ADLs and leads to regular disability, unsafe conditions, and poor quality of life (Edemekong *et al.*, 2017). The significance of administering these tests, concerning identifying the disability, is also twofold in that it will

indicate the amount of rehabilitation and care needed by the impaired individual (Edemekong *et al.*, 2021).

There have been many formulations and assessments created for testing these ADL levels. Many of them use scaling systems to indicate the severity of their inability to complete a task successfully (Mahoney & Barthel, 1965; Katz *et al.*, 1970; Jagur *et al.*, 2012). While additional indices were created to test the frailty standards among differing populations (Zedda *et al.*, 2021). There are a multitude of ADL identification and scoring criteria; however, for this research, these will only be limited to a generalised few that directly impact the fundamental needs of the individual namely: eating/drinking, communication, changing posture, manipulating objects and walking. In future research, the hope is that this can be scientifically expanded to produce a deeper understanding of these individuals' needs.

3.11. *Identifying Socio-economic Status*

Cribra orbitalia (CO), in its active form, is considered to occur at infancy and suggests that physical health and diet were not adequate for the individual (Walker *et al.*, 2009). With non-specific causes for its prevalence, it has been difficult to justify why it occurs, however most research points to malnutrition in some capacity within the individual (Walker *et al.*, 2009). This can be identified by porotic lesions found on the orbital roofs throughout the individual's life, with healing of these lesions often occurring as the individual ages and leads to a reduction in visibility of this pathology (Brickley, 2018). Similarly, linear enamel hypoplasia (LEH) has been known to present itself when an individual, is in the growing stages, when they are under physiological stress (El-Najjar *et al.*, 1978; Goodman & Rose, 1991; Hillson, 2014; Larsen, 2015). During this process, the enamel rods fail to form correctly and result in a narrow furrow around the circumference of the tooth (King *et al.*, 2002).

Enamel hypoplasia and cribra orbitalia are both known to be a marker of non-specific disease often linked to episodes of malnutrition and disease, often related to socio-economic status (Goodman & Rose, 1991; Ortner; 2003). Larsen (2015) summarises CO archaeological material over many localities and time periods and states that where individuals were in negative environmental conditions (poor hygiene, poor diet, overcrowding, disease ridden) the rates of cribra orbitalia increased. Similar findings with LEH occur, with famine and rural locations often being areas where there is a noted increase in this pathology (Larsen, 2015). Where individuals were involved in forced resettlement, a declining nutritional quality and

poor living conditions, the rates of LEH had increased significantly than those who did not (Larsen, 2015). This research does not negate that there are other factors that may induce both pathologies, however, in a climate where these conditions were very sparse for many living in South Africa this may provide a sufficient and justifiable reasoning for this relationship.

4. MATERIALS AND METHODS

4.1. Materials

4.1.1. Study Sample

The sample for this study was obtained from the Raymond A. Dart Collection of Modern Human Skeletal Collection, housed in the School of Anatomical Sciences at the University of the Witwatersrand. The Raymond A. Dart collection currently houses approximately three thousand skeletal remains (Dayal *et al.*, 2009). The collection was started in the 1920s, under the guidance of Raymond Dart, and has grown in diversity since. The importance of this collection has been highlighted by its use in various academic contexts (e.g., Saunders & DeVito, 1991; Fernandes, 2004; Bidmos, 2005; Steyn, 2019). For this research osteoarthritis (OA), intervertebral disc disease (IVDD), diffuse idiopathic skeletal hyperostosis (DISH) and spondylitis were all classified as a group and given the term degenerative joint disease (DJD). Including DISH in this classification system was done on the basis that there are similar symptomologies known to cause pain and inhibit movement (Mata *et al.*, 1997). Additionally, a study conducted by Rogers *et al.* (1997) shows that where DISH is present, it is difficult to differentiate between osteophytes and enthesophytes as they often cooccur.

An indicator sample of 315 individuals was identified as having some form of degenerative pathology. All these individuals were from the 1900s time period. These included males and females of all Southern African population groups and were identified from information contained in detailed hardcopy inventory sheets associated with the Dart collection. Lastly, DJD is typically seen in middle-aged individuals but may also occur in younger adults because of greater activity patterns (Marie, 2014). Therefore, the researcher viewed all individuals between the ages of 35 and 94.

After viewing the hard copy inventory sheets, the sample was refined by assessing each individual's skeleton to ascertain where the possible pathology was located and whether it conformed to the criteria of DJD as set out by Waldron (2009). During the extended sampling process, individuals presenting with any signs of DJD on the temporomandibular joint (TMJ), shoulder, elbow, wrist, finger, hip, knee, ankle, toe joints and the cervical, thoracic, and lumbar vertebral disc space were included.

The identification of DJD followed the definitions as set out by Waldron (2009: 27). These included:

1. The presence of marginal osteophytes and/or enthesophytes, represents the formation of new bone around the margins of the joint. Osteophytes are known as a new bone formation at the joint margin, and enthesophytes is bone formation that occurs at the ligament/tendon attachment sites.
2. Lipping of joint surfaces. This is the formation of new bone on the joint surface due to the vascularisation of the subchondral bone marrow.
3. Pitting on the joint surface. This is represented by a series of holes on the joint surface. It may occur as barely discernible pinpoint pitting is widely spaced holes in the articular surface, or as coalesced pitting, which are often larger and grouped, leading to greater weakening of the surface.
4. Changes in the normal contour of the joint, for example, widening or flattening of the contour.
5. Eburnation, which represents polished areas on the joint surface. In extreme cases, eburnation may be accompanied by scores or grooves.

Waldron (2009) states that should eburnation or at least two of the following be present: marginal osteophyte, new bone on the joint surface, pitting on the joint surface, or a modification in joint contour; DJD can be considered as existing. Those that did not fit into these criteria were excluded from this sample.

Table 1 represents the entirety of the individuals selected based on this research. “After DJD selection” refers to any pathological traits that were selected during the initial selection procedure and identified by a total of 315 individuals. From this, 150 individuals were selected to closely resemble the demographics of the DJD selected sample and used for the scoring of DJD and subsequent ADLs. The final sample highlights that the sample was stratified between males (52%) and females (48%). Whereas, within the population affinity there is a weaker representation of white individuals (23%) than black individuals (77%). The oldest age group also presented with the lowest representative percentage out of all the age categories (20%).

The combination of population affinity and sex resulted in some poorly stratified sub-categories. Black male individuals made up almost half of the entire final sample (47%), whereas white males are severely underrepresented (5%). While there appears to be a sampling bias for the white male sub-category, it closely matches what was available from

the entire DJD sample - 12 individuals. The final study sample (n=150) therefore mimicked the demographic distribution of the individuals in the Dart that displayed with some form of DJD (refer to Table 1).

Table 1. Comparison between initial and final selection

Categories	Sub-categories	After DJD selection	Final sample
		Number (%)	Number (%)
Total	Overall	315 (100)	150 (100)
Sex	Male	145 (47)	78 (52)
	Female	171 (53)	72 (48)
Population affinity	Black	230 (74)	116 (77)
	White	85 (26)	34 (23)
Population affinity & sex	Black female	97 (31)	27 (18)
	Black male	133 (42)	71 (47)
	White female	73 (23)	45 (30)
	White male	12 (4)	7 (5)
Age	35 – 54	121 (38)	49 (33)
	55 – 74	138 (44)	70 (47)
	75 – 94	56 (18)	31 (20)

4.1.2. Exclusion Criteria

Specific joints with DJD were excluded from the study if they had more than half of a joint surface and/or margin assessed in this study missing or severely damaged. Where signs of tuberculosis of the spine (Pott's disease) and cancer found in bone tissue (e.g., osteosarcoma) were present, the entire individual was excluded due to the potential influence of these diseases on joint surfaces (Dass *et al.*, 2002; Picci, 2007). In cases where some of the oldest remains in the collection were exposed to poor cleaning practices (rendering the joint surface unobservable) these were excluded. The atlantoaxial was excluded from this study as the axial scoring criteria does not allow for accurate scoring of the synovial, pivot joint.

The specific articular surfaces, bone joints, and regions used in this study are identified in Table 2 below.

Table 2. Degenerative joint disease classification system

Articular Surfaces	Bones	Joints	Region	
Mandibular condyle	Mandible	TMJ	TMJ	
Mandibular fossa	Temporal bone			
Head of humerus	Humerus	Shoulder	Upper peripheral	
Glenoid cavity	Scapula			
Trochlea of humerus	Humerus	Elbow		
Trochlea notch	Ulna			
Distal radial surface	Radius	Wrist		
Proximal scaphoid & lunate	Carpals			
Distal metacarpal surfaces on 1 st digit	Metacarpals	Fingers		
Proximal 1 st phalanx surfaces of 1 st digit	Phalanges			
Femoral head	Femur	Hip		Lower peripheral
Acetabulum	Pelvis			
Lateral & medial condyles	Femur	Knee		
Tibial plateaus	Tibia			
Distal tibial surface	Tibia	Ankle		
Lateral malleolus	Fibula			
Superior surface of talus	Tarsals			
Distal metatarsal surface of 1 st digit	Metatarsals	Toes		
Proximal 1 st phalanx surface of 1 st digit	Phalanges			
Inferior	Axis	Cervical vertebrae	Axial	
Superior	C3 - 7			
Inferior				
Superior	T1 - 12	Thoracic vertebrae		
Inferior				
Superior	L1 - 5	Lumbar vertebrae		
Inferior				
Superior	S1			

4.2. Methods

After sampling, a skeletal inventory was taken for each individual included in the final study sample. The skeletal inventory ensured that the data analysis phase of the study can account for missing or damaged skeletal regions which may affect the sample sizes of the individual joint regions.

4.2.1. Documenting the Extent and Severity of Degenerative Joint Disease

This objective is concerned with the scoring of DJD and its severity for each individual's joint surfaces. Each individual's skeletal remains were positioned in the anatomical order according to White & Folkens (2005).

Only morphological/macrosopic classification methods were used in the assessment of DJD. Keeping within Kilgore's (1985) criteria, the body was separated into vertebral and non-vertebral scoring systems. Each joint region was scored using the criteria set out by Kilgore (1985) and Buikstra *et al.* (1994) for the peripheral skeleton but with substantial refinements and clearer descriptions that were developed by the researcher (described further in section 4.1.1a). Similarly, the axial skeleton followed the scoring of Kilgore (1985) and Rojas-Sepúlveda *et al.* (2008). The difference with this study lies within the separation and distinction between each of the phases and their individual characteristics (described further in section 4.1.1b).

The scoring methodology proposed by Kilgore (1985), Buikstra *et al.* (1994) and Rojas-Sepúlveda *et al.* (2008) was found to be too broad for this research and failed to capture the different nuances and variations amongst this sample. Additionally, the previous methods failed to account for DISH in their observations, which was included in this research. For this reason, this study set out to adapt the original scoring criteria proposed by Kilgore (1985) and Buikstra *et al.* (1994) to account for additional variation and the inclusion of DISH.

Before the commencement of scoring and to enable refinement of the scoring criteria, the researcher familiarised themselves with where each joint began and ended, as well as the motion of articulation. This was pertinent when scoring the joints as there is a differentiation between perpendicular and parallel joint interference as described in the criteria below. The scoring criteria used in this study were as follows:

a. Non-vertebral (TMJ, Upper peripheral and Lower peripheral joints)

Stage 1 was presented as an indicator as to whether any DJD pathology was present or not. Where the slightest signs of pathology were present, at any articular joint surface, the score was identified as falling within this section. Stage 1 was noted as having one or more of the following characteristics present:

- (1) Any barely discernible marginal lipping on the joint surface. Lipping represented minimal bony projection away from the joint surface or a slight ridge that formed around the edge (Fig. 1).
- (2) Any small, pinpoint porosities present anywhere on or around the articular surface (Fig. 2).
- (3) Osteophytes and/or enthesophytes characterised by rounded and/or slightly raised single/isolated bony growths (Fig. 3).

In addition to these characteristics, both of the following criteria must be met for Stage 1:

- (4) The joint surface shows no signs of eburnation.
- (5) The joint surface shows no contour changes.

This stage presents the beginning stages of DJD present within the individual joint.

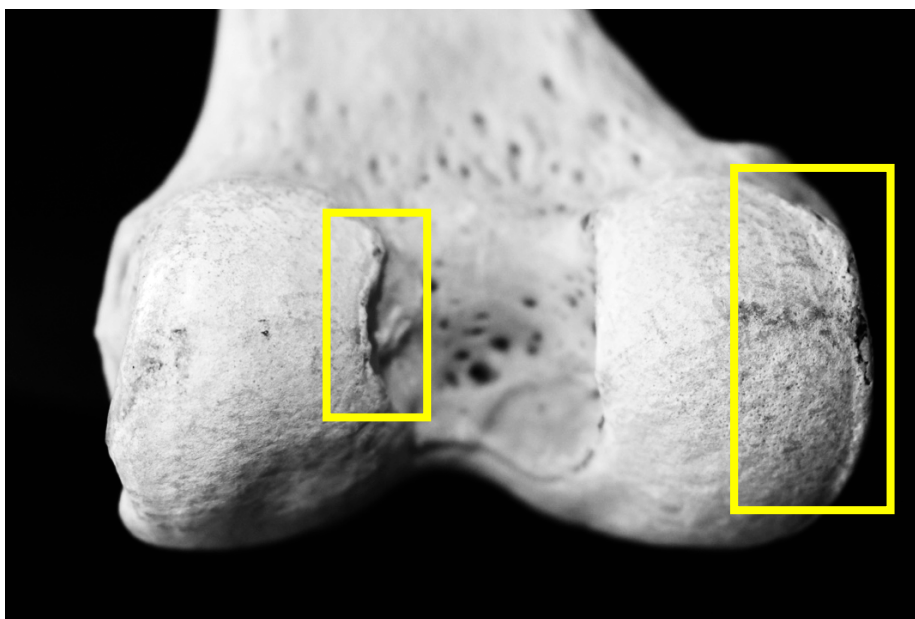


Figure 1. Stage 1 - Lipping on distal femur

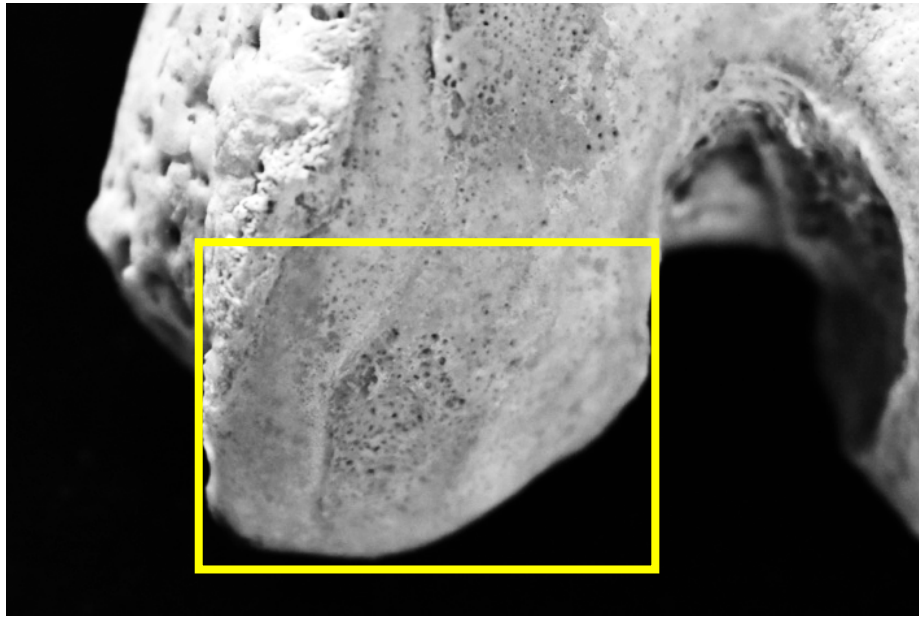


Figure 2. Stage 1 - Pinpoint porosity on distal femur

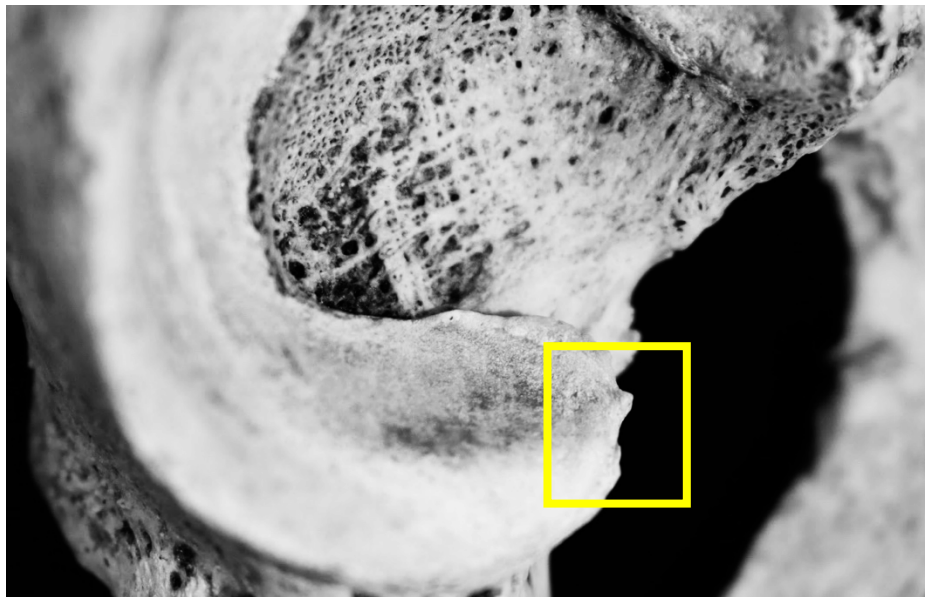


Figure 3. Stage 1 - Osteophyte on acetabulum

Stage 2 was identified as having moderate characteristics of DJD being present. This stage was noted as having one or more of the following characteristics present:

- (1) Pronounced or elevated lipping projecting away and usually parallel to the joint surface. Lipping does not yet enter the joint surface (Fig. 4).
- (2) The presence of coalesced porosity found anywhere on the articular surface (Fig. 5).

- (3) Multiple, well-defined osteophytes present at the joint margin and/or enthesophytes found around the surface (Fig. 6).
- (4) Slight eburnation may be present on the joint surface (Fig. 7).
- (5) Contour changes such as the widening or flattening of the articular surface. This may also occur as a result of coalesced pitting, eburnation, and entheses on the joint surface (Fig. 8).

This criterion presents substantial structural changes to the articular surface within this stage.

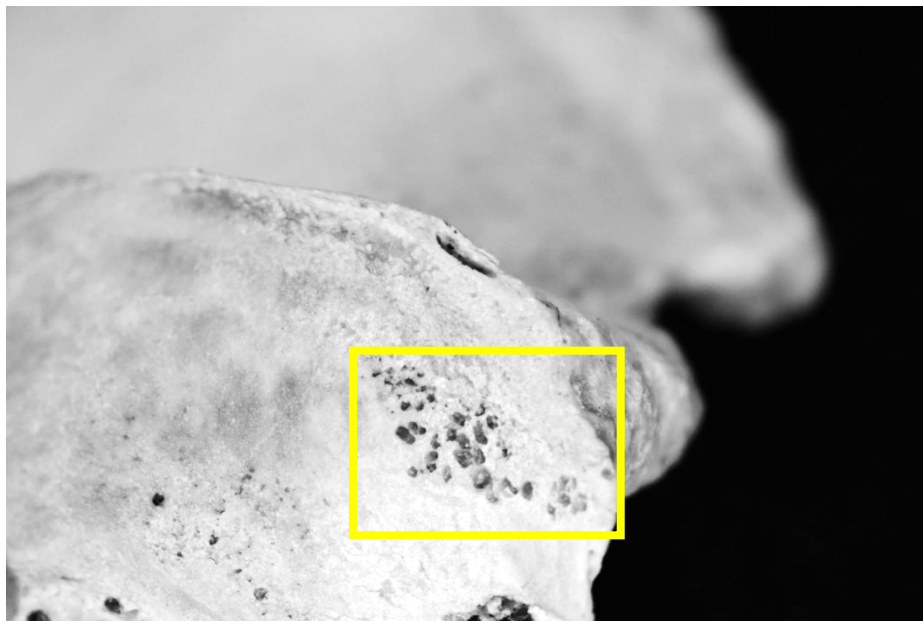


Figure 4. Stage 2 - Coalesced porosity on acetabulum

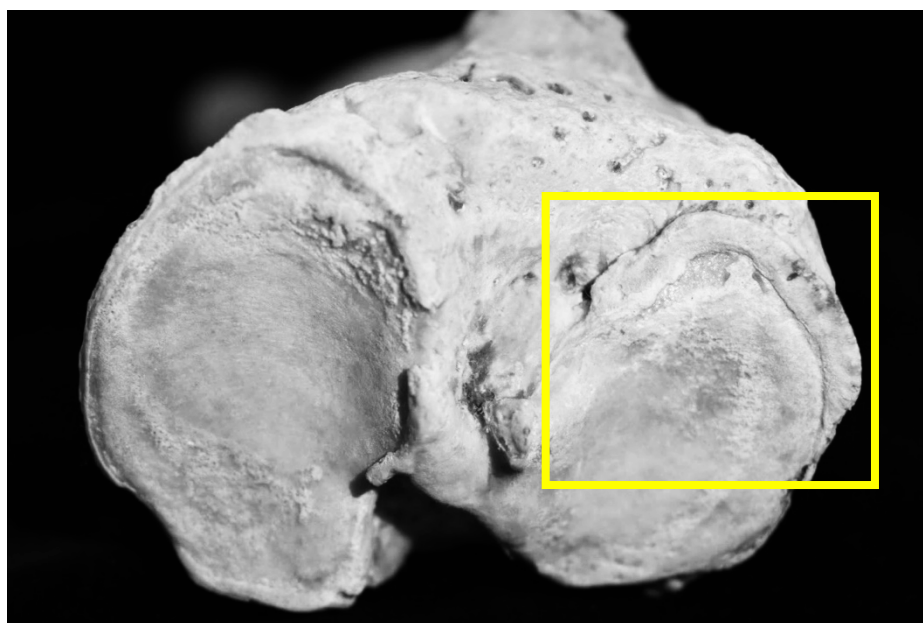


Figure 5. Stage 2 - Lipping on proximal tibia

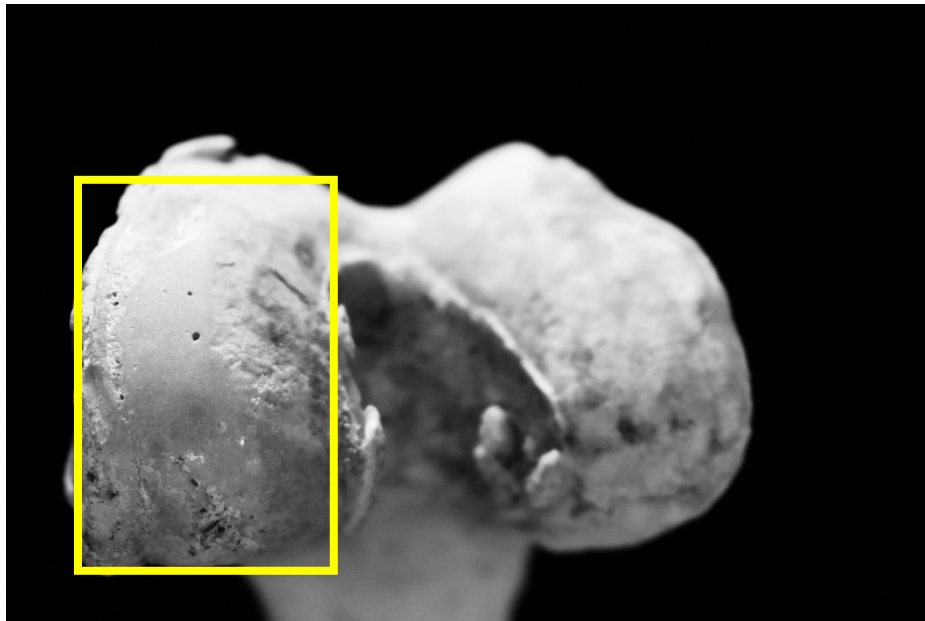


Figure 6. Stage 2 - Eburnation on distal femur

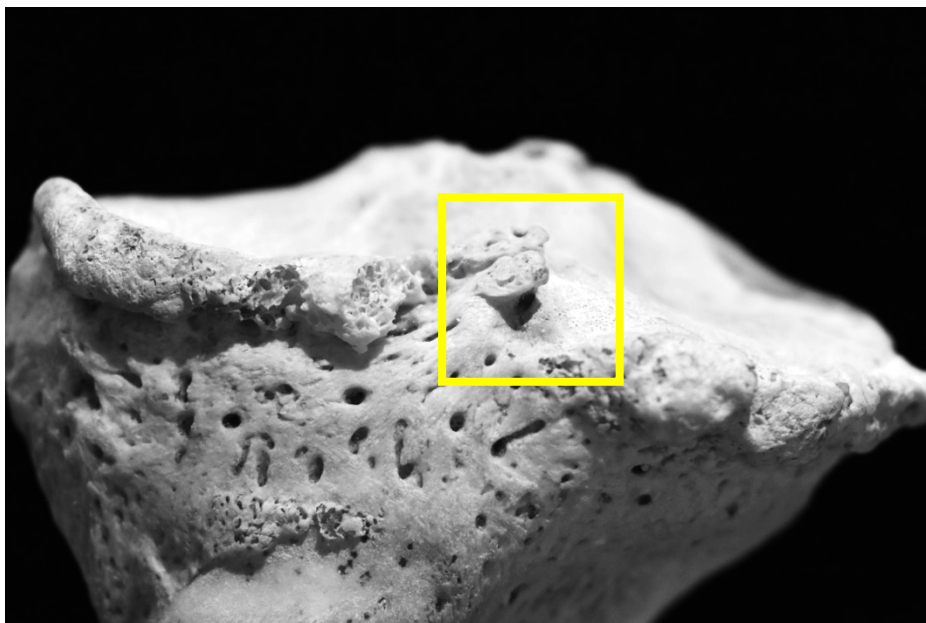


Figure 7. Stage 2 - Osteophyte on proximal tibia

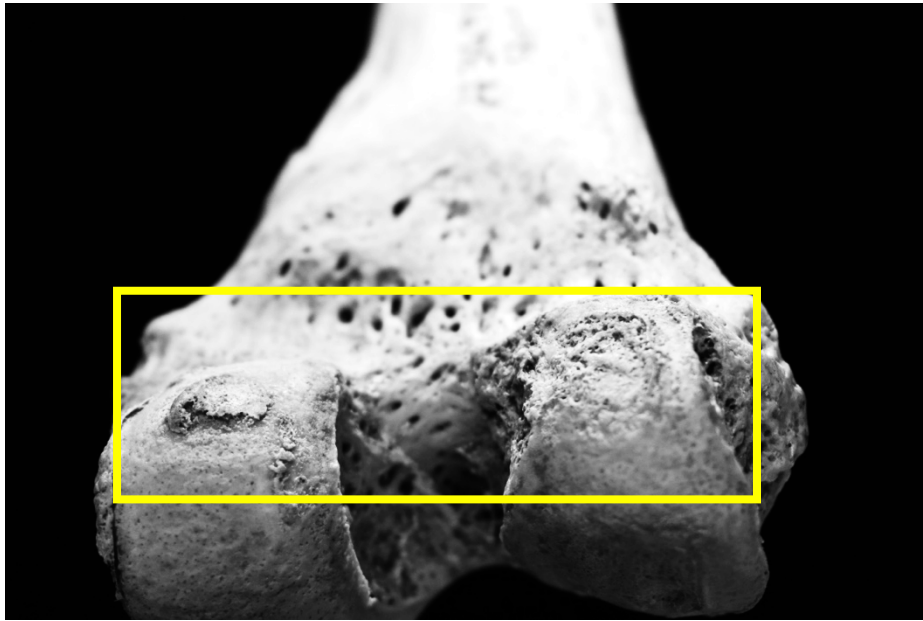


Figure 8. Stage 2 - Contour changes on distal femur

Stage 3 was identified as having severe characteristics of DJD being present. These were identified as interfering with the joint surface in the form of possible obstructions. Severe degenerative changes were identified as including one or more of the following:

- (1) Extensive, often irregular, lipping running adjacent to the articular surface, often pronounced, and curling inward, towards the same joint surface or to the opposing bony joint surface (Fig. 9).
- (2) Pinpoint and coalesced porosity present within the same area of the joint (Fig. 10).
- (3) Extensive osteophytic and/or enthesophyte growth seen around the articular surface. These projections must project towards the opposite bony joint surface and or curve inwards towards its joint surface. The presence of entheses may be more common and more pronounced at this stage (Fig. 11).
- (4) More extensive eburnation often presenting with additional grooving of the joint surface (Fig. 12).
- (5) More prominent contour changes in the form of deep depressions caused by more extensive porosity and grooved eburnation (Fig. 13).

This stage presents the total breakdown of cartilage and structures within the articular surface.

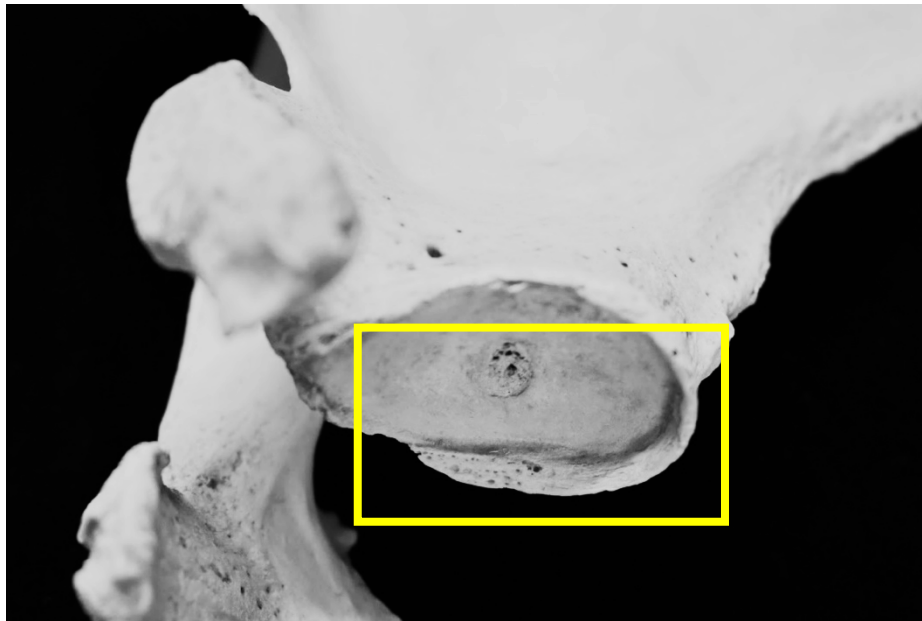


Figure 9. Stage 3 - Lipping on glenoid cavity

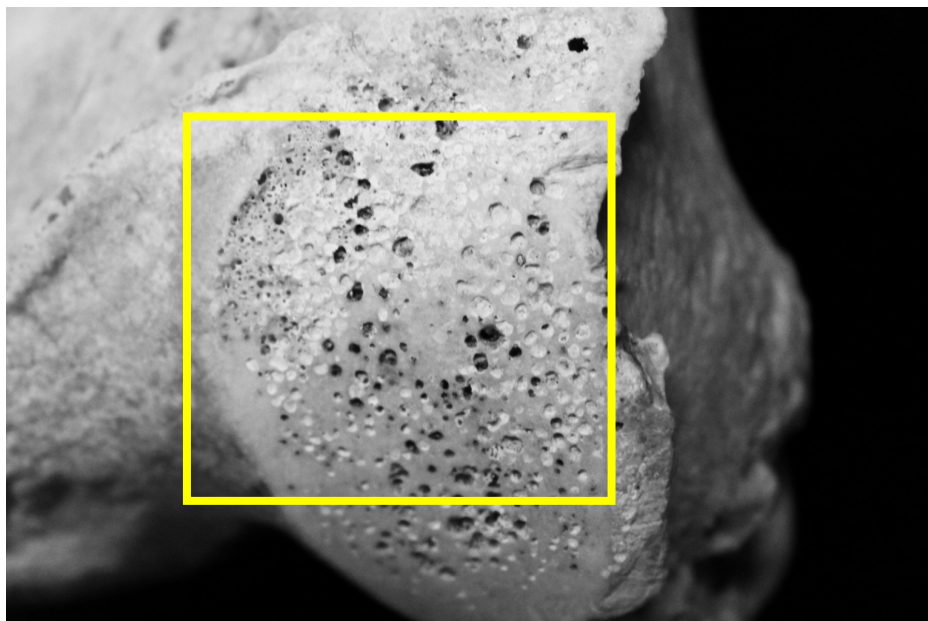


Figure 10. Stage 3 - Pinpoint & coalesced porosity on the femoral condyle

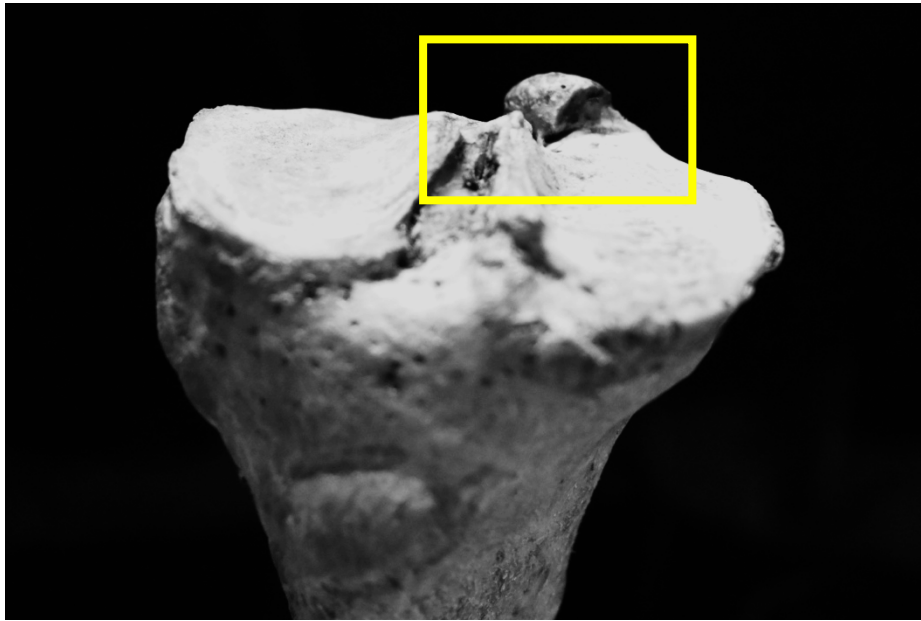


Figure 11. Stage 3 - Enthesophyte on proximal tibia

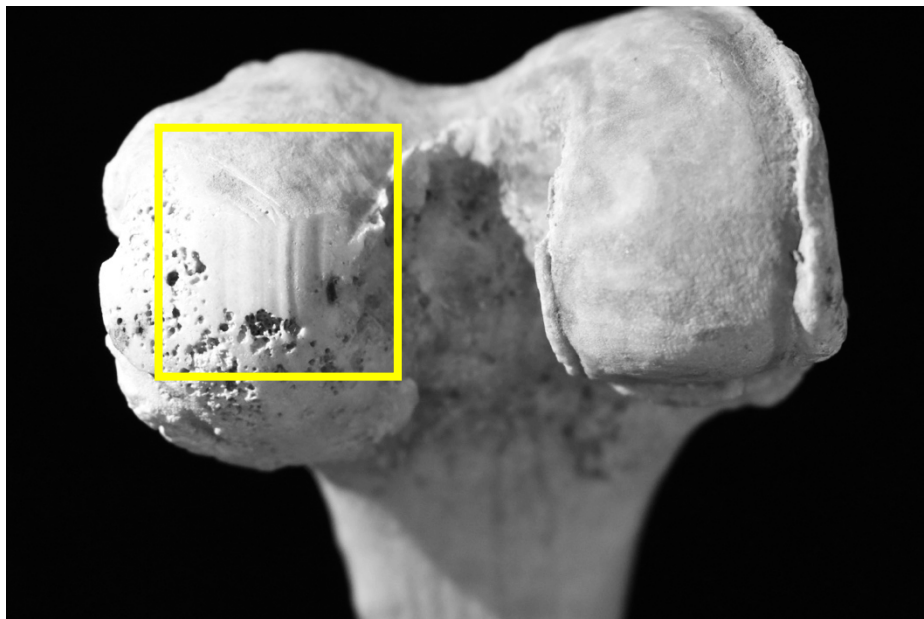


Figure 12. Stage 3 - Eburnation with grooves on distal femur

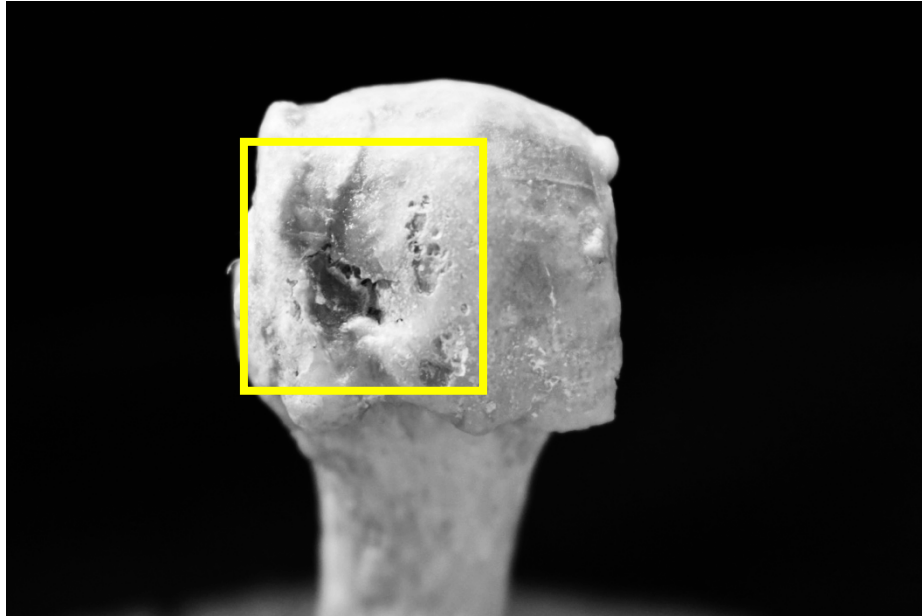


Figure 13. Stage 3 - Contour changes on distal metatarsal

When accounting for the various joints within the wrist (scaphoid and lunate) and ankle (tibia and fibula) the most severe of the articular surfaces were used. When assessing at the hand (metacarpophalangeal) and foot (metatarsophalangeal) the 1st digit was used. Both the left and right sides of the peripheral regions were scored where present.

b. Vertebral (Axial joints)

Only the vertebral body rims were assessed for DJD (Fig. 14). This is applicable for all cervical, thoracic, lumbar, and sacral vertebrae that presented with bodies. The rib facets on the thoracic vertebrae were not assessed for signs of DJD.

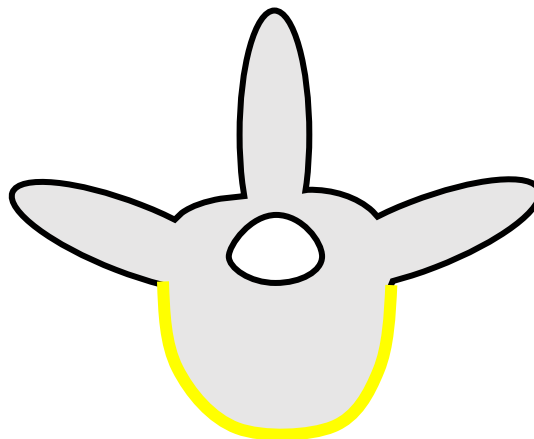


Figure 14. Scoring area for vertebra

The following stages were used to score axial DJD. Stage 1 was presented if one or more of the following characteristics were present:

- (1) Barely discernible marginal lipping present on the anterior aspect of the rim of the vertebral body. This is defined as slight lipping present, which shows slight projection away from the vertebral body. The lipping should be present on more than 50% of the rim (Fig. 15).
- (2) Small, pinpoint porous changes to the anterior aspect of the disc space towards the rim edge (Fig. 16).
- (3) No osteophytes or enthesophytes should be present at this point.
- (4) No eburnation should be present at this point.

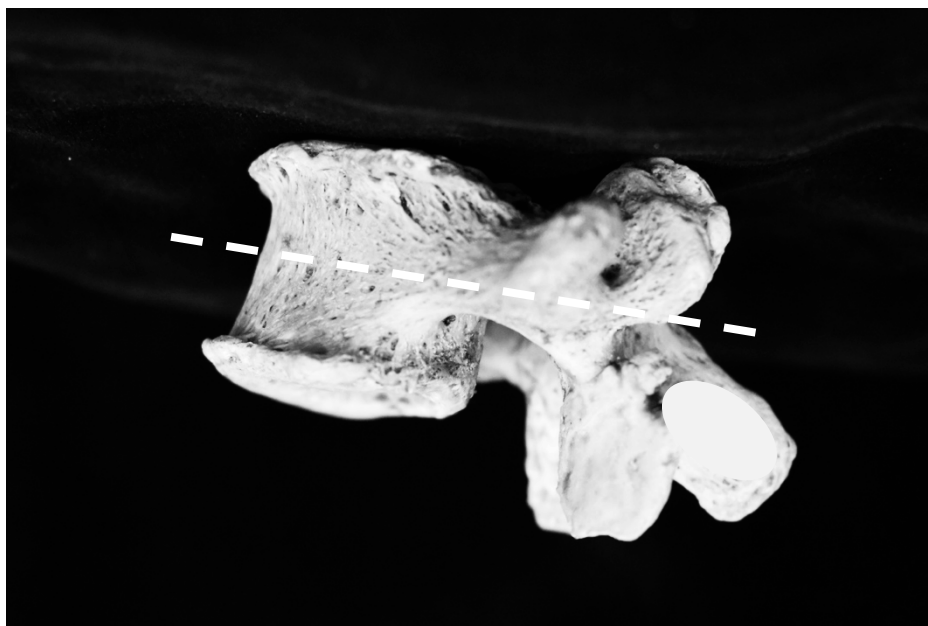


Figure 15. Stage 1 - Lipping on lumbar vertebra

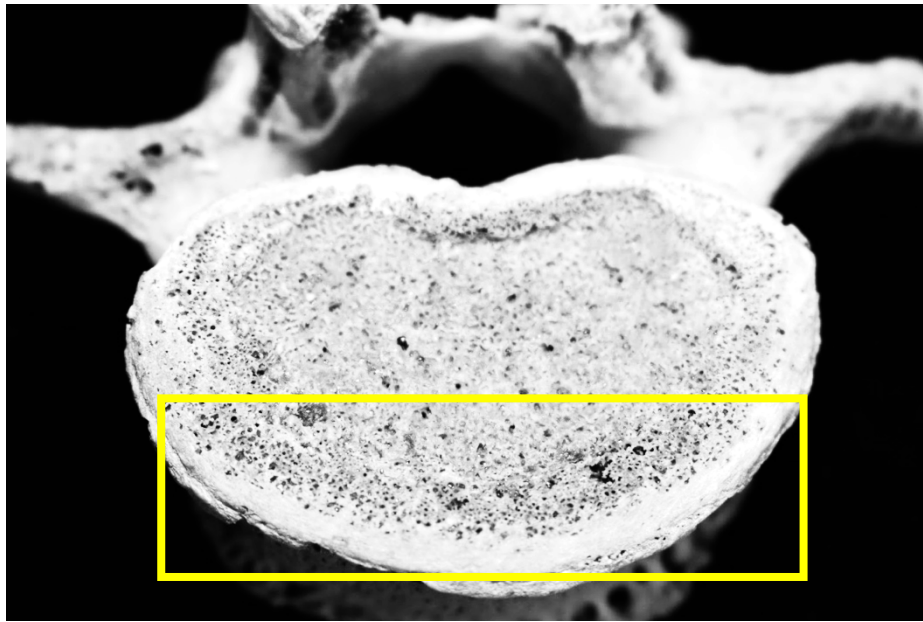


Figure 16. Stage 1 - Pinpoint porosity on lumbar vertebra

Stage 2 was identified as having prominent characteristics of DJD being present. This stage was noted as having one or more of the following characteristics present:

- (1) Moderate lipping, projecting horizontally away from vertebral body rim. This stage can only be classified as such where there is no lipping extending towards the horizontal line of the body plane (Fig. 17).
- (2) Coalesced pitting on the anterior aspect of the disc space may be present (Fig. 18).
- (3) Osteophyte or enthesophyte formation may occur with a single projection towards the horizontal plane of the vertebral body, superiorly or inferiorly (Fig. 19).
- (4) No eburnation is present at this stage.

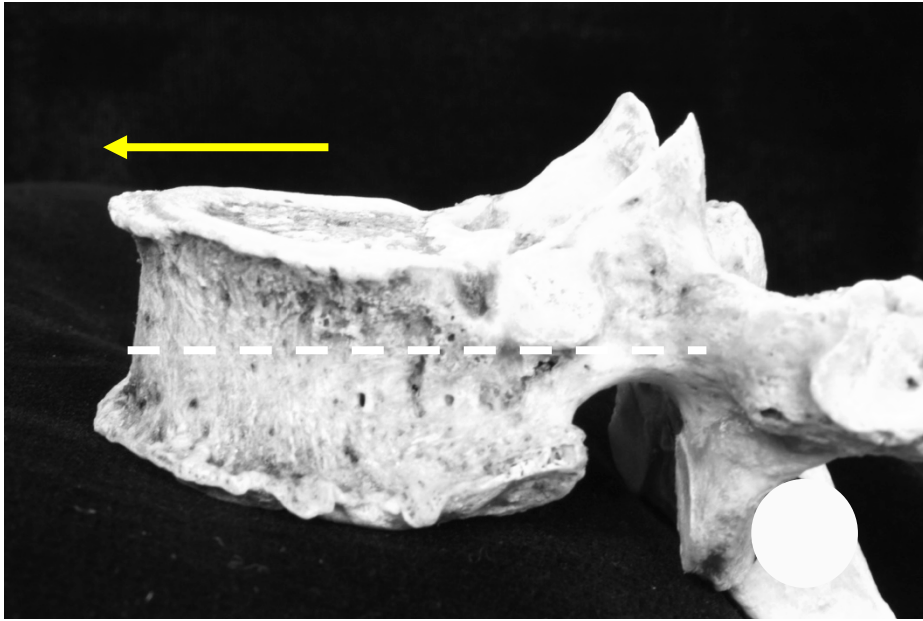


Figure 17. Stage 2 - Lipping on thoracic vertebra

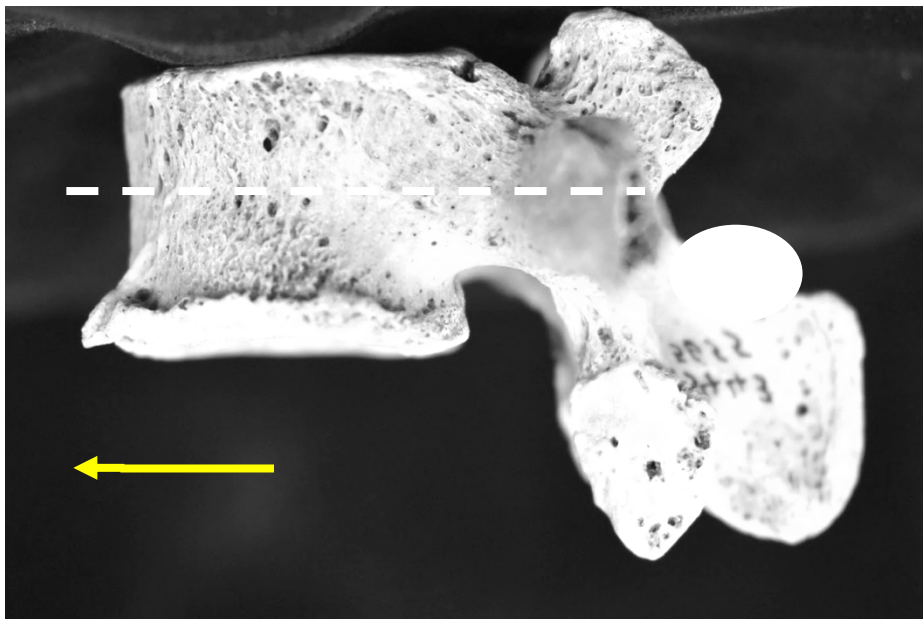


Figure 18. Stage 2 - Osteophyte on lumbar vertebra

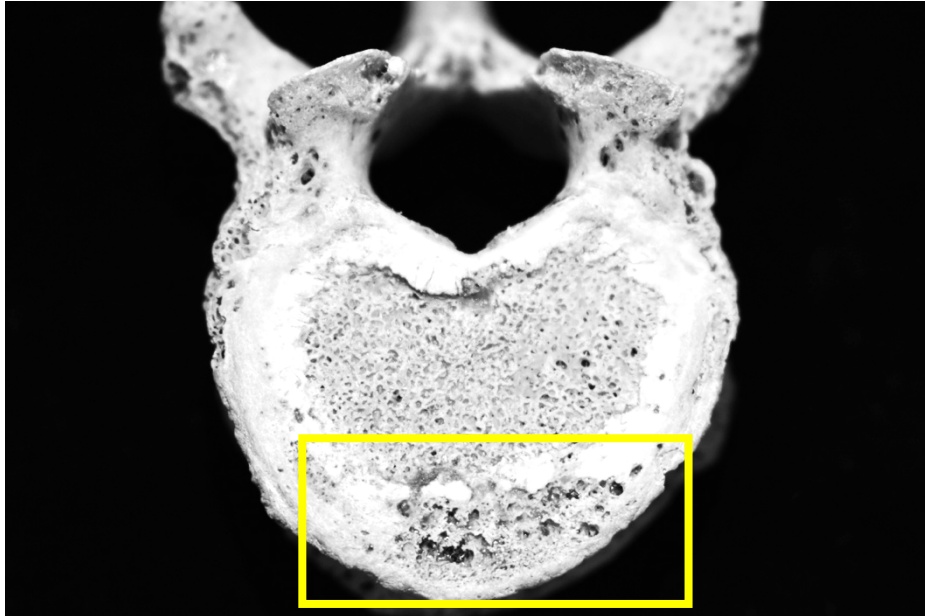


Figure 19. Stage 2 - Coalesced porosity on thoracic vertebra

Stage 3 was identified as having severe characteristics of DJD being present. These were identified as interfering with the joint surface whereby bony obstructions preventing movement may be present. Severe degenerative changes included one or more of the following:

- (1) Extensive lipping, projecting vertically beyond the superior or inferior vertebral body rim (Fig. 20).
- (2) Extensive pinpoint and coalesced porosity on the anterior aspect of the disc space (Fig. 21).
- (3) Projection of multiple osteophytes and/or enthesophytes beyond the margin of the rim on either the superior or inferior surfaces. Either may be more pronounced presenting with multiple projections on a single surface (Fig. 22).
- (4) Eburnation on the anterior aspect of the disc space may be present at this stage (Fig. 23).

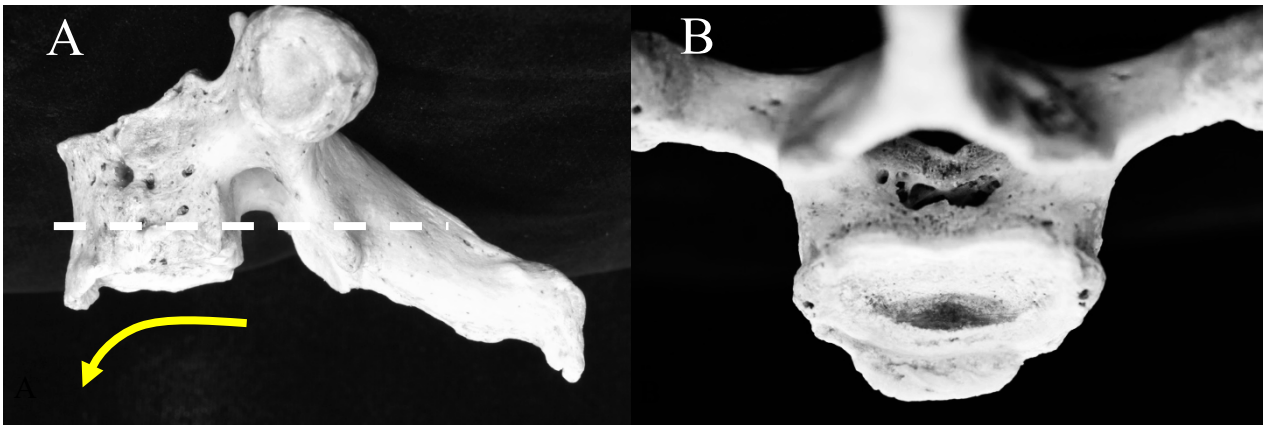


Figure 20. Stage 3 - Lipping on thoracic vertebra (A) sagittal and (B) dorsal view

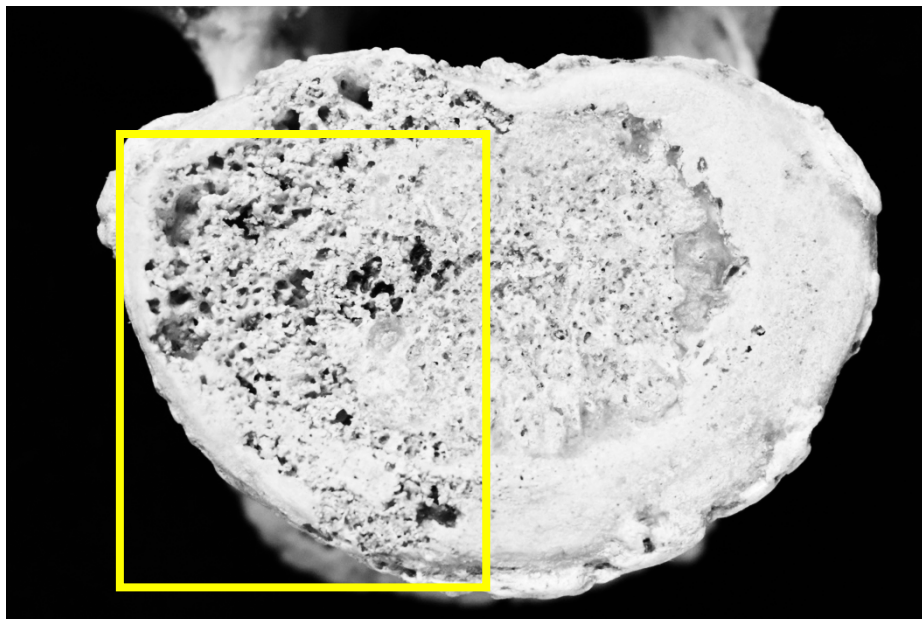


Figure 21. Stage 3 - Extensive pinpoint & coalesced porosity on lumbar vertebra



Figure 22. Stage 3 - Enthesophyte on lumbar vertebra

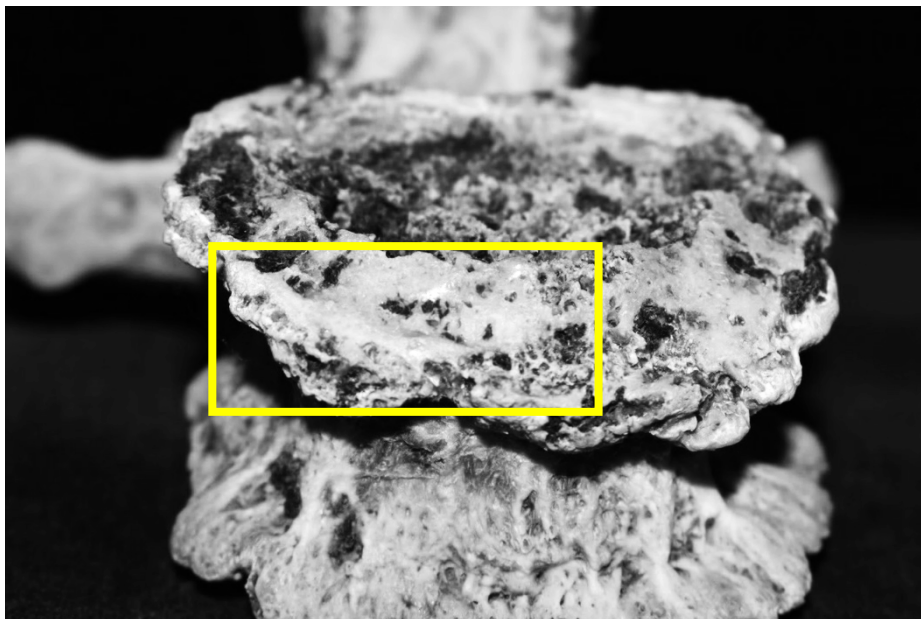


Figure 23. Stage 3 - Eburnation on the superior surface of a lumbar vertebra

Stage 4 was identified as bony fusion. This can be identified as total fusion of two or more articular surfaces due to either osteophytes and/or enthesophytes merging (Fig. 24 & 25).

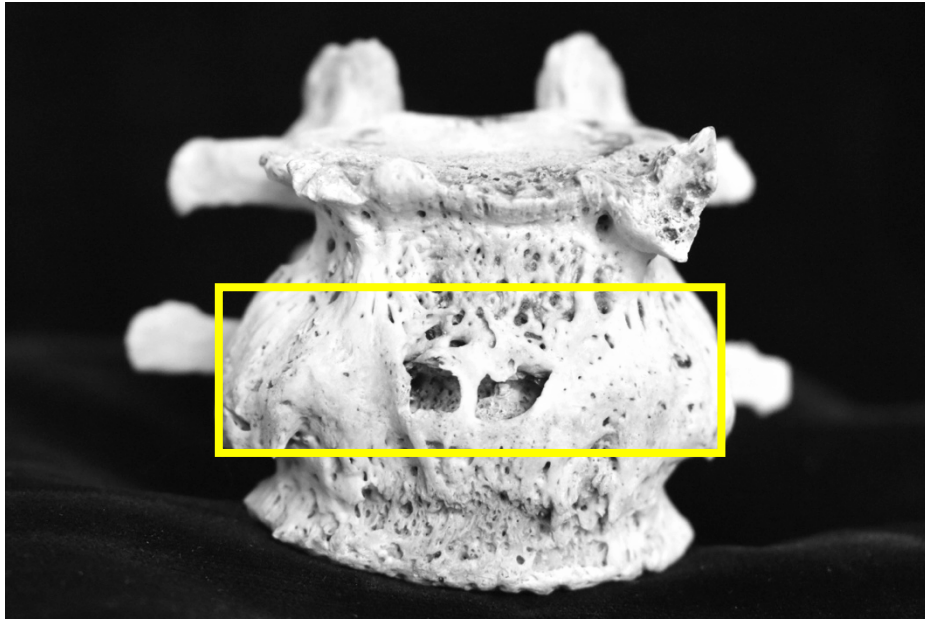


Figure 24. Stage 4 - Complete Fusion on lumbar vertebra

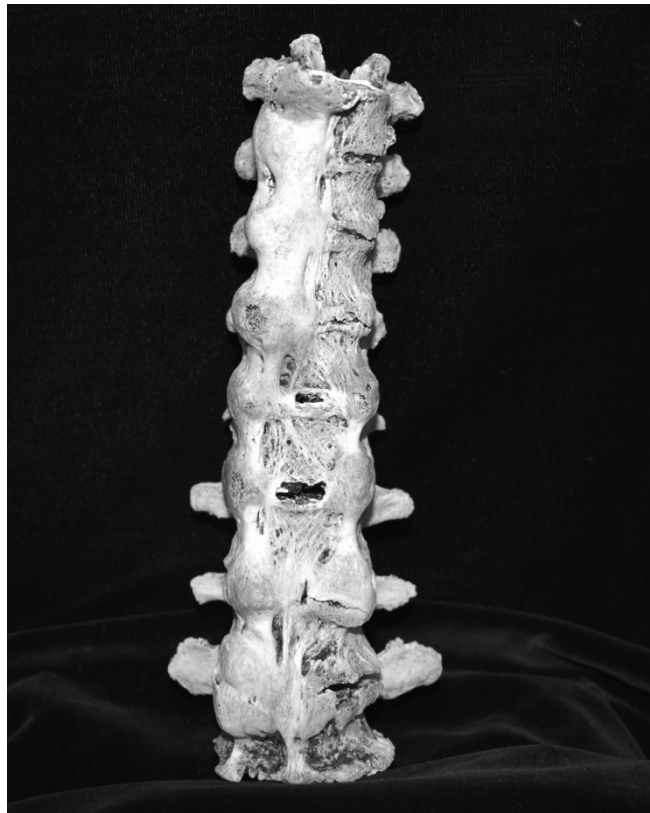


Figure 25. Stage 4 - Fusion caused by DISH

To allow for joint region scores to be compiled the following rules were followed. For the peripheral skeleton, the most severe stage observed on any of the joint surfaces assessed was used as the basis for the joint region score. For example, where the humeral head presented as a stage 2 and the glenoid fossa as a stage 3 the shoulder joint region would be scored as a stage 3. For the axial skeleton to obtain a score for each vertebral region, the scores obtained for each of the vertebral bodies in each region (cervical, thoracic and lumbar) were used. The highest score across the most vertebra, was the score that was used per region.

The data obtained from this meant that each joint has one possible score, this is defined as the joint score. Each individual presented with the following joint scores: TMJ, shoulder, elbow, wrist, finger, hip, knee, ankle, toe, cervical, thoracic and lumbar unless damaged beyond use. This information was compiled into various frequency tables, translated into percentages, and compared. Mean scores were also calculated for each joint and reported. Welch's t-tests were used when comparing means across different demographics for any differences or similarities that could be noted. Severity was reported as the mean scores present, whilst frequency was reported as the number of individuals that were divided into their respective scores. Pearson correlation coefficients were conducted on age, this was done to see if there was a positive or negative correlation with age in relation to DJD. Where positive the joint was understood to have been highly influenced by age. If the coefficient was negative, this was taken that while age may still have played a role, there may be other factors that are more specific to DJD in that specific joint.

4.2.2. Determining the Level of Impairment in Each of the Proposed Activities of Daily Living as these Relate to Specific Joint Regions

For this objective, the identification of limitations of Activities of Daily Living (ADL) was scored based on the outcome of the joint region DJD scores. Impairment of joints brought on by degenerative changes and nerve impingement often manifests as pain and can range from partial to complete immobilization of the joint affected (Buchanan & Kean, 2002; Sinusas, 2012). Several authors have suggested ways in which impairment and ADLs can be scored (Mahoney & Barthel, 1965; Katz *et al.*, 1970; Laplante & DePalma, 2012; Stamm *et al.*, 2016). However, these methods are mainly conducted using an in-person or inference-based model, the former requiring living participants to rate their functionality. However, clinical literature on the impacts of DJD on joint regions may be used to guide the researcher in

understanding the possible effects pain and impaired mobility would have on specific joint regions and as such infer the impact on ADLs. The below table highlights literature where ADL impairments have been noted concerning specific joints and their clinical manifestations that occur at these sites.

Table 3. ADL Impairments related to clinical manifestations

Joint	Clinical Limitations	ADL Impairments	References
TMJ	Pain Movement limitation rotations & anterior translation	Eating Speaking	Emsoff & Rudisch, 2003 Ibi, 2019 Alakailly <i>et al.</i> , 2017
Shoulder	Pain Movement limitation especially in external rotation & abduction	Moving objects Transferring Eating Bathing	Chillemi & Franceschini, 2013 Millett <i>et al.</i> , 2008
Elbow	Pain Movement limitation in flexion and extension	Activities involving flexion or extension Eating	Doherty & Preston, 1989 Kozak <i>et al.</i> , 1998 Ravalli <i>et al.</i> , 2019
Wrist	Pain Movement limitation in ulnar wrist flexion & radial wrist extension	Drinking Object manipulation (Less significance than other upper peripheral joints)	Weiss & Rodner, 2007 Adams <i>et al.</i> , 2003 Laulan <i>et al.</i> , 2015
Finger	Grip & pinch strength and movement limitation Pain	Eating Object manipulation	Domett <i>et al.</i> , 2017 Buchanan & Kean, 2002
Hip	Movement limitation in internal & external rotation Pain Balance Muscle weakness	Walking Sitting/Squatting	Domett <i>et al.</i> , 2017 Cinulka <i>et al.</i> , 2009 Buchanan & Kean, 2002 Dreyfuss <i>et al.</i> , 2004
Knee	Movement limitation in flexion and extension Pain Muscle weakness & lateral instability	Walking Squatting	Domett <i>et al.</i> , 2017 Bobes Álvarez <i>et al.</i> , 2021 Buchanan & Kean, 2002
Ankle	Pain Joint dysfunction Limited movement in plantar flexion	Walking Squatting Standing	Van Valburg <i>et al.</i> , 1999 Queen, 2017

Table 3. ADL Impairments related to clinical manifestations

Toes	Locomotor disability on the first metatarsophalangeal joint Balance Pain on ambulation	Walking Balancing	Roddy & Menz, 2018 Munteanu <i>et al.</i> , 2012 Sinusas, 2012
Cervical vertebrae	Pain Range of neck motion	Change in posture Head rotation	Özdemir <i>et al.</i> , 2001
Thoracic vertebrae	Pain Movement limitation	Axial rotation Lateral bending	Gellhorn <i>et al.</i> , 2013 Laplante & DePalma, 2012 Hou <i>et al.</i> , 2016
Lumbar vertebrae	Pain Movement limitation	Bending Flexibility	Goode <i>et al.</i> , 2013 Niosi & Oxland, 2004

The following is a novel contribution to combining ADLs with their proposed respective diseased joint regions. Where the ability to eat or drink is concerned, this was linked directly to the TMJ and upper peripheral joints when getting food to the mouth and processing it for swallowing. The ability to communicate verbally is linked specifically with the TMJ and the functionality of forming words for speech. The ability to change posture (for example, bending, twisting, extension, head rotation) is often associated with the vertebrae, making up the axial joints. The ability to manipulate objects associated with the peripheral joints of the hand. Lastly, the ability to walk is associated with the lumbar and thoracic vertebrae, as well as the lower peripheral joints.

No methods currently exist to score ADLs in the deceased. Therefore, for this study, a novel scoring system was used to enable the scoring of ADLs based on the joint region DJD scores. The ADLs were categorised according to the specific joint region affected by DJD, whilst considering the severity of DJD as established in objective 1. This will then link the joint region affected by DJD with a specific ADL activity. The ADLs are correlated with the respective joint as follows.

- Talking: TMJ
- Eating: TMJ, elbow, wrist and finger joints
- Transferring: shoulder, elbow and wrist joints
- Walking: Hip, knee, ankle and toe joints
- Object manipulation: finger joints
- Posture changes: Cervical, thoracic and lumbar vertebra

- Head rotation: Cervical vertebra
- Twisting: Thoracic vertebra
- Bending: Lumbar vertebra

For this objective, where there is a slight DJD present, no ADL score is assigned. Where slight DJD was concerned, there may not have been any significant change in the original joint structure and may ultimately not lead to a significant physiological manifestation. Where there is moderate DJD present, this was considered as individuals experiencing anything from no effect to pain. Due to this characteristic, it was given a score of “slight” ADL impairment. This inference is based on knowing that the earliest clinical manifestation of OA, is pain (Zedda *et al.*, 2021). On the other end of the scale would be complete DJD immobility (fusion), which is considered complete immobility of that particular joint (Kilgus *et al.*, 1990). This characteristic subsequently received an ADL impairment score of “severe”. Essentially this creates two ends of a scale, and it then dictates that where severe DJD was present, this was considered as individuals experiencing anything from severe pain and significant mobility reduction. Due to this information, a “moderate” ADL impairment score will be allocated. This is summarised in Table 4 below.

Table 4. ADL Scoring Criteria

DJD Score (Range)	ADL Score
Slight ($x \geq 1$)	None
Moderate ($x \geq 2$)	Slight
Severe ($x \geq 3$)	Moderate
Complete ($x \geq 4$)	Severe

The data obtained from each ADL meant that there was only one possible score, defined as the ADL score. Each individual presented with the following ADL scores: talking, eating, transferring, walking, object manipulation and postural change (divided into head rotation, twisting and bending). This information was compiled into various frequency tables, translated into percentages, and compared. Mean scores were also calculated for each joint and reported. Welch’s t-tests were used when comparing means across different demographics for any differences or similarities that could be noted. Severity was reported as the mean scores present, whilst frequency was reported as the number of individuals that

were divided into their respective scores. Chi-squared tests were employed to determine if any of the scores were statistically significant..

4.2.3. Explore any Possible Trends in Disability as Seen in Different Socio-Economic Contexts Between DJD and ADLs in the Sample

Socio-economic status (SES) is known to have a significant correlation with aspects such as physical labour and wear and tear all of which are significant when understanding the pathology of DJD (Barker, 1994; Kirkwood, 1996). The aforementioned aspects are due to a myriad of demographic parameters, including sex, age, and population affinity – all of which were recorded for each of the individuals included in the final study sample. To identify any potential effects socio-economic differences may have on the expression of DJD, permission was obtained from the curator and the Collections Committee to access information about the individual's donation status and occupation. The donation status can either be reported as “unclaimed” or “donated”. Unclaimed bodies primarily came from the Gauteng provincial hospitals until 1985, some of these are thought to consist of migrant labourers (Dayal *et al.*, 2009). Donated bodies represent individuals that bequeathed their remains, or were bequeathed on their behalf by family members, to universities for the benefit of medical science (Brits *et al.*, 2020).

SES could play a factor in the rate of DJD and disability, with research showing obesity as a contributory factor, alongside physical labour and the overuse of mechanical mechanisms causing wear and tear (Barker, 1994; Kirkwood, 1996). The SES recorded in this study was based on the donation status and assessment of specific pathology. A donation status of “donated” was assigned to individuals who were suspected to have a higher SES, whereas a donation status of “unclaimed” was assigned to individuals who were thought to have lower SES. In addition, linear enamel hypoplasia (LEH) and cribra orbitalia (CO) (Fig. 26 & 27) have, in the past, been used as a measure of the quality of life in children and subsequent effects on late adult life and will assist in determining SES in this study (Cucina & Işcan, 1997; Robb, 2001; Miskiewicz, 2015). Unfortunately, as with all methods, this is not a fool-proof system, and the researcher was cognisant that childhood experiences and SES may not reflect the adult status (Amoroso *et al.*, 2014). The presence of LEH and CO was, therefore, taken as a sign of physiological stress and these individuals were classified as being of possible lower SES. The table below indicates the SES breakdown given the characteristics given above:

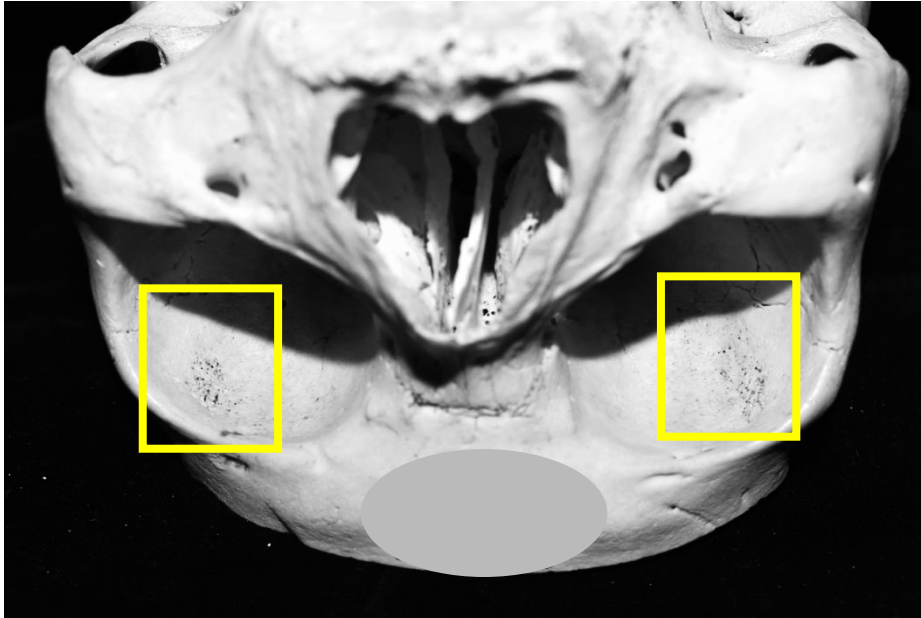


Figure 26. Criba orbitalia



Figure 27. Enamel hypoplasia

Table 5. Socio-economic status categorisation

SES Status	Lower SES	Lower SES	Lower SES	Higher SES
Donation Status	Unclaimed	Unclaimed	Donated	Donated
LEH and/or CO	Present	Not present	Present	Not present

The data obtained allowed for the entire sample to be divided into lower and higher SES individuals. Again, frequency tables were created to see if there was any discernible difference between the two socio-economic statuses and the joint scores between them. Welch's t-tests were run to determine if there was any statistical significance between the two subsamples. As there was a potential for age to skew the data, Welch's t-tests were run on a controlled age of (55- 75 years) and frequency tables for ADLs were drawn up based on the same criteria.

4.2.4. Inter- and Intra-reliability

The methodology was re-run by the researcher on a sub-sample of 15 individuals from the original sample of 150 individuals. These were blind and chosen at random so no bias could influence the researcher. The same conditions were given for this analysis with an effort to minimise any external factors as best as possible. For the inter-reliability, a researcher well versed in pathology repeated the study on the same sub-sample of 15 individuals. The researcher was equipped with the same conditions and the sample was blind and chosen at random to limit bias. The reliability and repeatability of this method are vital for the study and the accomplishing of objective 1. A Weighted Cohen's Kappa was used to determine rater agreement. According to the weighting, re-evaluated by McHugh (2012), any value above 0.90 should be seen as an almost perfect agreement. In cases where the k value is between 0,6 and 0,79, this is seen as a moderate agreement.

All statistical tests were run in Microsoft® Excel for Mac, Version 16.80 (23121017) and IBM Statistical Package for Social Sciences (SPSS), Version: 28.0.1.1(15).

4.3. Ethics

Studies on skeletal remains housed in the School of Anatomical Sciences, University of the Witwatersrand are covered by an ethics waiver as they were donated for research by provisions of the National Health Act (Act 61 of 2003) and the South African Human Tissues Act (No. 65 of 1983). This allows for ethical research to be done on human remains. The

ethics number which allowed the researcher in School of Anatomical Sciences to gain access to this waiver is - **W-CBP-220504-01**.

5. RESULTS

5.1. Inter- and Intra-reliability

Both inter- and intra-reliability tests of the DJD scoring system were run using Weighted Cohen's Kappa statistic on 10% ($n = 15$) of the sample size. The vertebral and non-vertebral regions were calculated individually for both tests, given that the scoring criteria for these two regions are different. Intra-reliability for the non-vertebral region resulted in a value of $k = 0.942$, $p < 0.001$ and slightly lower for the vertebral region at $k = 0.917$, $p < 0.001$ indicating an almost perfect agreement for both. For inter-reliability, a kappa value of 0.627, $p < 0.001$ was obtained for the non-vertebral region and a kappa value of 0.626, $p < 0.001$ for the vertebral region suggesting a moderate agreement across both (McHugh, 2012).

5.2. Data Normality Testing

Data was tested using a Shapiro-Wilk test for normality. This indicated that all the datasets had a normal distribution with $p > 0.05$, therefore the null hypothesis that the data was normally distributed was not rejected and all subsequent statistical tests were parametric.

5.3. DJD Extent and Severity

5.3.1. Overall

The DJD mean severity scores per joint type obtained in this study are represented in Table 6. The axial joints were the only regions presenting with a DJD score of 4, as fusion was only seen in this region.

Table 6 showcases the severity percentages for each of the joint types in the pooled sample. The highest severity percentages per region were observed in the shoulder, with 64 (42,67%) individuals, followed by the knee, with 39 (26,17%) individuals and the hip, with 38 (25,50%). All three these joints presented with a severity score of 3. Very few individuals presented with a severity score of 0 for the upper peripheral joints with none of the individuals presenting with a score of 0 for the elbow, whereas for the lower peripheral joints the hip was affected in all but one individual. The TMJ on the other hand showed a general low severity compared to other joints, where there were 49 (33%) individuals who showed no signs of DJD. For the axial skeleton, severity scores were much more variable across different vertebral regions, with the highest severity percentage per region was seen in the thoracic vertebra (5,37%).

The highest mean DJD severity score obtained in the pooled sample was also observed for the shoulder joint (2,20) in the upper peripheral skeleton, followed by the hip joint (2,01) for the lower peripheral skeleton and lumbar vertebral joints (1,73) for the axial skeleton.

Table 6. An overview of DJD throughout the entire sample

Joint Region	Sample (N)	Severity Score (N)						Severity Percentage (%)					Mean Severity Score
		0	1	2	3	4		0	1	2	3	4	
Upper Peripheral Skeleton													
TMJ	150	49	50	40	11	-		32,67	33,33	26,67	7,33	-	1,09
Shoulder	150	2	30	54	64	-		1,33	20,00	36,00	42,67	-	2,20
Elbow	150	0	44	76	30	-		0,00	29,33	50,67	20,00	-	1,91
Wrist	150	2	65	74	9	-		1,33	43,33	49,33	6,00	-	1,60
Fingers	150	2	36	86	26	-		1,33	24,00	57,33	17,33	-	1,91
Lower Peripheral Skeleton													
Hip	149	1	32	78	38	-		0,67	21,48	52,35	25,50	-	2,01
Knee	149	13	47	50	39	-		8,72	31,54	33,56	26,17	-	1,76
Ankle	150	10	81	47	12	-		6,67	54,00	31,33	8,00	-	1,41
Toe	150	20	58	50	22	-		13,33	38,67	33,33	14,67	-	1,49
Axial Skeleton													
Cervical	150	63	25	48	13	1		42,00	16,67	32,00	8,67	0,67	1,09
Thoracic	149	80	35	15	11	8		53,69	23,49	10,07	7,38	5,37	0,87
Lumbar	149	29	26	53	38	3		19,46	17,45	35,57	25,50	2,01	1,73

- Denotes that this section had no individuals present

5.3.2. Sex

For each respective section results, the average ages of cohorts will be given. This and previous research (Aufderheide & Rodriques-Martin 1998; Waldron, 2009; Marklein *et al.*, 2016) have indicated a relationship between age and DJD, and therefore, by highlighting this information the differences in scores can be better understood. The mean age of females and males was noted as 65,81 years and 58,73 years, respectively. Considering mean age and comparing DJD in male and female populations the differences here indicate that DJD was shown to be present earlier in the male population.

In Table 7, 40% of the male sample scored 3 in the shoulder joint and the hip received 29,87%, with the knee slightly lower at 29,49%. The thoracic vertebral joint for score 4 was relatively high at 6,49%; however, the lumbar vertebral joint is worth noting as score 3 was over a third of the entire male population (33,77%). The elbow and finger joints indicated that all individuals showed some sign of DJD. Within the female cohort well over 45% of

individuals who scored 3 in the shoulder joint. Similarly, the females more frequently (47,22%) scored above 2 and 3 for the TMJ. The knee and toe joints are also highly impacted, with over 22% of the cohort over a score of 3 across both cohorts. The thoracic vertebral joint in both cohorts indicated 4% and higher of individuals scored a 4, and 16,67% of individuals scoring 3 for the lumbar vertebral joints.

From Table 7, the following peripheral joint regions presented with higher mean severity scores in the female individuals: TMJ (males = 0,88; females = 1,31), shoulder (males = 2,13; females = 2,28), fingers (males = 1,86; females = 1,96), hip (males = 2,00; females = 2,03), toe (males = 1,33; females = 1,67). The male population showed higher scores for the elbow (males = 1,96; females = 1,85), wrist (males = 1,65; females = 1,54), knee (males = 1,77; females = 1,75), and ankle (males = 1,46; females = 1,35).

For the axial joints the female individuals presented with higher mean severity scores: cervical (males = 1,01; females = 1,18) and thoracic (males = 0,81; females = 0,93) vertebral joints, and the males with a higher mean severity score in the lumbar (males = 1,79; females = 1,67) vertebral joints.

A Welch's t-test was conducted between male and female sexes and found that the TMJ ($p = 0,006$) and the toe ($p = 0,023$) joints presented with statistically significant higher mean severity scores in the females compared to males.

Table 7. Comparing male and female DJD mean severity scores

Joint Region	Males							Females						
	Sample (N)	Severity Percentage (%)					Mean Severity	Sample (N)	Severity Percentage (%)					Mean Severity
		0	1	2	3	4			0	1	2	3	4	
Upper Peripheral														
TMJ	78	35,90	42,31	19,23	2,56	-	0,88	72	29,17	23,61	34,72	12,50	-	1,31
Shoulder	78	1,28	24,36	34,62	39,74	-	2,13	72	1,39	15,28	37,50	45,83	-	2,28
Elbow	78	0,00	24,36	55,13	20,51	-	1,96	72	0,00	34,72	45,83	19,44	-	1,85
Wrist	78	1,28	37,18	56,41	5,13	-	1,65	72	1,39	50,00	41,67	6,94	-	1,54
Fingers	78	0,00	29,49	55,13	15,38	-	1,86	72	2,78	18,06	59,72	19,44	-	1,96
Lower Peripheral														
Hip	78	1,30	24,68	44,16	29,87	-	2,00	72	0,00	18,06	61,11	20,83	-	2,03
Knee	78	10,26	32,05	28,21	29,49	-	1,77	71	7,04	30,99	39,44	22,54	-	1,75

Table 7. Comparing male and female DJD mean severity scores

Ankle	78	6,41	48,72	37,18	7,69	-	1,46	72	6,94	59,72	25,00	8,33	-	1,35
Toe	78	11,54	51,28	29,49	7,69	-	1,33	72	15,28	25,00	37,50	22,22	-	1,67
Axial														
Cervical	78	42,31	20,51	30,77	6,41	0,00	1,01	72	41,67	12,50	33,33	11,11	1,39	1,18
Thoracic	77	59,74	18,18	9,09	6,49	6,49	0,81	72	47,22	29,17	11,11	8,33	4,17	0,93
Lumbar	77	22,08	12,99	29,87	33,77	1,30	1,77	72	16,67	22,22	41,67	16,67	2,78	1,67

- Denotes that this section had no individuals present

5.3.3. Population Affinity

Only individuals of Southern African black and white population affinity were present in this research sample. There are substantial age differences between these two cohorts. The black population had a mean age of 58,9 years, while the white population had a mean age of 71,15 years. The black cohort made up a large number of individuals who showed signs of DJD at a younger age period.

The black population affinity highlighted in Table 7 below, indicated that just over 40% of this cohort had scored 3 for the shoulder joint. After this, there is only the knee joint (25%) with a quarter of individuals showing a score of 3. The remainder of the peripheral joints sit below this 25% mark. The thoracic vertebral joints seem to have the most fusions (score 4) with just below 5% affected, and just below 30% of lumbar vertebral joints affected with a score of 3. Lastly, for this population, there was only the elbow joint where every individual showed signs of some form of DJD change. This is in contrast to the white population affinity, where the shoulder, elbow, wrist, and hip joints all showed signs of some DJD. Half of the white cohort saw a score of 3 for the shoulder joint. The hip, knee and toe joints all indicated a score of 3 of over 30%, which is not seen in the black population group. Lastly, again the thoracic vertebral joint showed the most fusion (score 4) across all the axial joints with a score of over 8%, and the lumbar vertebral joint had nearly a third of the cohort with a score of 3.

Table 8 highlights the differences in the average joint DJD scores between these two groups in the study sample. The following peripheral joint regions presented with higher mean severity scores in the white individuals: the TMJ (black = 0,93; white = 1,67), the shoulder (black = 2,15; white = 2,38), the wrist (black = 1,59; white = 1,65), the fingers (black = 1,90; white = 1,94), and the hip (black = 1,93; white = 2,29) and the toes (black = 1,41; white =

1,79). Whereas in the black individuals, higher mean severity scores were observed in the elbow (black = 1,98; white = 1,65), the knee (black = 1,77; white = 1,74) and the ankle (black = 1,47; white = 1,18) joints.

For the axial joints, the white individuals presented with higher mean severity scores in the cervical (black = 0,97; white = 1,50), thoracic (black = 0,64; white = 1,65) and lumbar (black = 1,70; white = 1,82) vertebrae.

A Welch's t-test showed that the higher mean DJD severity scores observed in the TMJ ($p = 0.0001$), the toe ($p = 0,03$), the cervical ($p = 0,01$) and thoracic ($p = 0,0001$) vertebral joints of the white individuals were statistically significant compared to the black individuals. The higher mean severity scores observed in the elbow ($p = 0,01$) and the ankle joints ($p = 0,04$) for the black individuals were also found to be statistically significant compared to the white individuals.

Table 8. DJD between black and white affinity individuals

Joint Region	Black Affinity							White Affinity						
	Sample (N)	Severity Percentage (%)					Mean Severity	Sample (N)	Severity Percentage (%)					Mean Severity
		0	1	2	3	4			0	1	2	3	4	
Upper Peripheral Skeleton														
TMJ	116	37,93	35,34	22,41	4,31	-	0,93	34	14,71	26,47	41,18	17,65	-	1,67
Shoulder	116	1,72	22,41	35,34	40,52	-	2,15	34	0,00	11,76	38,24	50,00	-	2,38
Elbow	116	0,00	24,14	53,45	22,41	-	1,98	34	0,00	47,06	41,18	11,76	-	1,65
Wrist	116	1,72	42,24	51,72	4,31	-	1,59	34	0,00	47,06	41,18	11,76	-	1,65
Fingers	116	0,86	25,86	56,03	17,24	-	1,90	34	2,94	17,65	61,76	17,65	-	1,94
Lower Peripheral Skeleton														
Hip	115	0,87	25,22	52,17	21,74	-	1,93	34	0,00	8,82	52,94	38,24	-	2,29
Knee	116	7,76	32,76	34,48	25,00	-	1,77	33	12,12	27,27	30,30	30,30	-	1,74
Ankle	116	5,17	50,86	35,34	8,62	-	1,47	34	11,76	64,71	17,65	5,88	-	1,18
Toe	116	12,07	44,83	33,62	9,48	-	1,41	34	17,65	17,65	32,35	32,35	-	1,79
Axial Skeleton														
Cervical	116	47,41	14,66	28,45	8,62	0,00	0,97	34	20,59	23,53	44,12	8,82	2,94	1,50
Thoracic	115	63,48	20,87	7,83	3,48	4,35	0,64	34	20,59	32,35	17,65	20,59	8,82	1,65
Lumbar	115	24,35	13,91	31,30	27,83	2,61	1,70	34	14,71	20,59	32,35	32,35	0,00	1,82

- Denotes that this section had no individuals present

5.3.4. Population Affinity and Sex

a. White Males

The mean age for the white male cohort was 67,57 years. Although the sample size is extremely small there are some interesting notes to highlight. The shoulder and the hip show close to 60% of individuals in this cohort with a score of 3. There was no sign of DJD score 3 in the TMJ, the fingers and score 4 in the cervical and lumbar vertebral joints. All individuals had at least some form of DJD in the TMJ, the shoulder, the elbow, the wrist, the finger, the hip, the ankle joints, and the thoracic vertebral joints. Almost 15% of these individuals had fusion (score 4) in the thoracic vertebral joints.

Across all joint regions, the shoulder and hip joints for the peripheral region, and the thoracic vertebral joint for the axial region had the highest mean severity scores. This trend largely followed what was seen in the overall sample data regarding the peripheral skeleton (Table 8), with the white males presenting with higher mean severity scores in relation to all males in the shoulder (2,57), and hip (2,57). In the axial skeleton, there is a change where thoracic (2,29) had a higher mean average over the lumbar region vertebral joints. This information is seen in Table 9:

Table 9. DJD scores across the white male sub-sample

Joint Region	Sample (N)	Severity Percentage (%)					Mean Severity Score
		0	1	2	3	4	
Upper Peripheral Skeleton							
TMJ	7	0,00	28,57	71,43	0,00	-	1,71
Shoulder	7	0,00	0,00	42,86	57,14	-	2,57
Elbow	7	0,00	28,57	28,57	42,86	-	2,14
Wrist	7	0,00	42,86	42,86	14,29	-	1,71
Fingers	7	0,00	28,57	71,43	0,00	-	1,71
Lower Peripheral Skeleton							
Hip	7	0,00	0,00	42,86	57,14	-	2,57
Knee	7	14,29	42,86	0,00	42,86	-	1,71
Ankle	7	0,00	42,86	42,86	14,29	-	1,71
Toe	7	28,57	14,29	28,57	28,57	-	1,57
Axial Skeleton							
Cervical	7	14,29	71,43	14,29	0,00	0,00	1,00
Thoracic	7	0,00	28,57	28,57	28,57	14,29	2,29
Lumbar	7	14,29	28,57	28,57	28,57	0,00	1,71

- Denotes that this section had no individuals present

b. Black Males

The mean age for the black male cohort was 58,18 years, which is substantially lower than the white male cohort. Here fewer individuals are presenting with a score of 3 for the shoulder TMJ with only 38% affected. The knee and hip both follow closely with just below 30% of individuals presenting with a score of 3. Again, the thoracic vertebra saw the most fusion with over 5% receiving a score of 4; however, the lumbar vertebral joint was substantially high with over a third of individuals presenting with a score of 3. In this cohort, only the elbow and finger joints showed any signs of DJD.

The black male individuals (Table 10) represent nearly half of the entire sample. The joints with the highest affected mean severity scores are the shoulder joint (2,08), the hip joint (1,97) and the lumbar vertebral joint (1,80).

Table 10. DJD scores across black male sub-sample

Joint Type	Sample (N)	Percentage Score (%)					Mean Severity Score
		0	1	2	3	4	
Upper Peripheral Skeleton							
TMJ	71	39,44	43,66	14,08	2,82	-	0,80
Shoulder	71	1,41	26,76	33,80	38,03	-	2,08
Elbow	71	0,00	23,94	57,75	18,31	-	1,94
Wrist	71	1,41	36,62	57,75	4,23	-	1,65
Fingers	71	0,00	29,58	53,52	16,90	-	1,87
Lower Peripheral Skeleton							
Hip	70	1,43	27,14	44,29	27,14	-	1,97
Knee	71	9,86	30,99	30,99	28,17	-	1,77
Ankle	71	7,04	49,30	36,62	7,04	-	1,44
Toe	71	9,86	54,93	29,58	5,63	-	1,31
Axial Skeleton							
Cervical	71	43,66	15,49	32,39	7,04	0,00	1,01
Thoracic	70	65,71	17,14	7,14	4,29	5,71	0,67
Lumbar	70	22,86	11,43	30,00	34,29	1,43	1,80

- Denotes that this section had no individuals present

c. Black Females

The mean age for the black female cohort was 60,07 years. From the table below there are 44,44% of the cohort that show signs of score 3 within the shoulder joint. The following joints show that over 20% of the cohort had a score of 3 for the elbow (29%) and the knee

(20%) joints. The axial skeleton shows that the lumbar vertebral joints had the highest scores 3 and 4, with 18% and 4% respectively. Lastly, only the elbow and hip joints indicated some form of DJD across the cohort.

Black female individuals (Table 11) presented similar patterns seen in the other cohorts, except for the elbow. Here, the shoulder, elbow and lumbar vertebral joints presented the highest mean severity score per joint region. The highest mean severity score from black females was then compared to their respective data for all females for the shoulder (2,24), elbow (2,04) and lumbar (1,56) vertebral joints.

Table 11. DJD scores across black female sub-sample

Joint Type	Sample (N)	Percentage Score (%)					Mean Severity Score
		0	1	2	3	4	
Upper Peripheral Skeleton							
TMJ	45	35,56	22,22	35,56	6,67	-	1,13
Shoulder	45	2,22	15,56	37,78	44,44	-	2,24
Elbow	45	0,00	24,44	46,67	28,89	-	2,04
Wrist	45	2,22	51,11	42,22	4,44	-	1,49
Fingers	45	2,22	20,00	60,00	17,78	-	1,93
Lower Peripheral Skeleton							
Hip	45	0,00	22,22	64,44	13,33	-	1,91
Knee	45	4,44	35,56	40,00	20,00	-	1,76
Ankle	45	2,22	53,33	33,33	11,11	-	1,53
Toe	45	15,56	28,89	40,00	15,56	-	1,56
Axial Skeleton							
Cervical	45	53,33	13,33	22,22	11,11	0,00	0,91
Thoracic	45	60,00	26,67	8,89	2,22	2,22	0,60
Lumbar	45	26,67	17,78	33,33	17,78	4,44	1,56

- Denotes that this section had no individuals present

d. White Females

Lastly, the mean age for the white female cohort was 75,37 years substantially higher than that of the black female cohort. Almost half of these individuals had a score of 3 for the shoulder joint across the entire cohort. The hip and toe joints closely followed with a quarter of the cohort presenting with a score of 3. The thoracic vertebral joints presented with 19% and 7%, for scores 3 and 4 respectively. Lastly, the shoulder, elbow, wrist, hip joints, and lumbar vertebral joint all showed some sign of DJD across the cohort.

The white female individuals (Table 12) continued the trend seen throughout. The highest mean scores were in the shoulder, the hip, and the lumbar vertebra for each joint region. White females' highest mean severity scores were compared to that of all females for the shoulder (2,33), hip (2,22) and lumbar (1,85) vertebral joints.

Table 12. DJD scores across white female sub-sample

Joint Type	Sample (N)	Percentage Score (%)					Mean Severity Score
		0	1	2	3	4	
Upper Peripheral Skeleton							
TMJ	27	18,52	25,93	33,33	22,22	-	1,59
Shoulder	27	0,00	14,81	37,04	48,15	-	2,33
Elbow	27	0,00	51,85	44,44	3,70	-	1,52
Wrist	27	0,00	48,15	40,74	11,11	-	1,63
Fingers	27	3,70	14,81	59,26	22,22	-	2,00
Lower Peripheral Skeleton							
Hip	27	0,00	11,11	55,56	33,33	-	2,22
Knee	26	11,54	23,08	38,46	26,92	-	1,81
Ankle	27	14,81	70,37	11,11	3,70	-	1,04
Toe	27	14,81	18,52	33,33	33,33	-	1,85
Axial Skeleton							
Cervical	27	22,22	11,11	51,85	11,11	3,70	1,63
Thoracic	27	25,93	33,33	14,81	18,52	7,41	1,48
Lumbar	27	0,00	29,63	55,56	14,81	0,00	1,85

- Denotes that this section had no individuals present

e. Cross-comparisons

White males are the least represented in the sample with a total number of 7 (5%). This number was not sufficient to run reliable statistical tests on, and therefore, limited observations can be made. From the sub-category that was collected (Table 8), some valuable descriptive results were obtained.

A comparison was conducted between white and black males (Fig. 28) and highlighted that DJD was higher in the white cohort in the peripheral region for the TMJ (white males = 1,71; black males = 0,80), shoulder (white males = 2,57; black males = 2,08), elbow (white males = 2,14; black males = 1,94), and wrist (white males = 1,71; black males = 1,65) joints; apart from the finger (white males = 1,71; black males = 1,87) joint. The lower peripheral region is more in line with the white male cohort, with DJD in the hip (white males = 2,57; black males = 1,97), ankle (white males = 1,71; black males = 1,44) and the toe (white males =

1,57; black males = 1,31) joints being higher in white males, and DJD in the knee (white males = 1,71; black males = 1,77) joints being more prevalent in black males.

The axial skeleton saw a change in joint comparison with black males presenting with higher mean score for the cervical (white males = 1,00; black males = 1,01) and lumbar (white males = 1,71; black males = 1,80) vertebral joints, whereas the white male cohort presented with a higher thoracic (white males = 2,29; black males = 0,67) vertebral joint mean score.

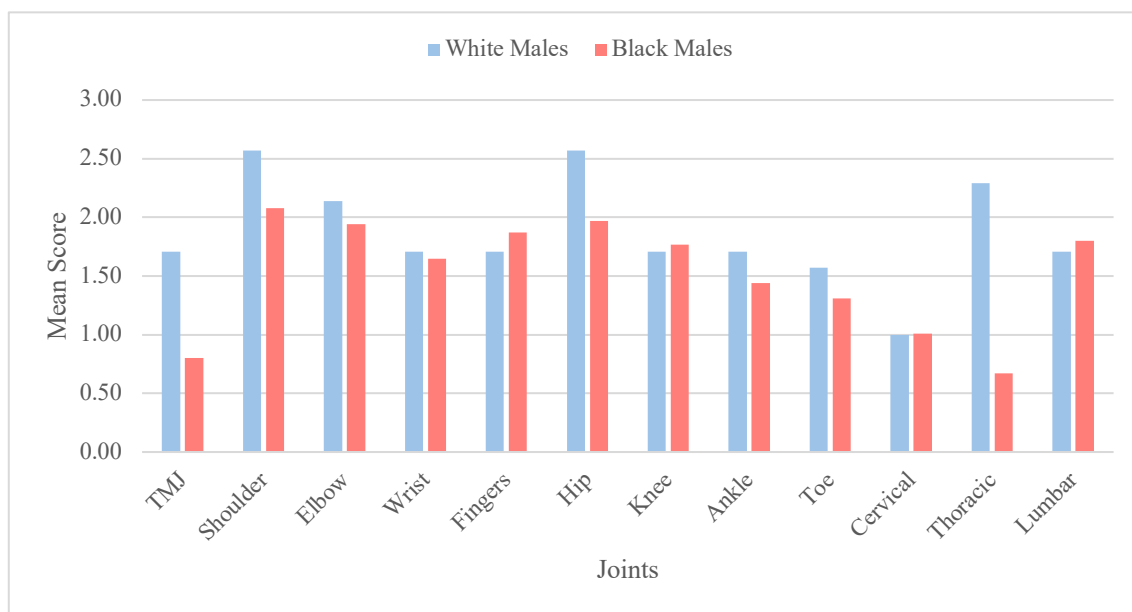


Figure 28. Comparing white male and black male DJD scores

A comparison between black males and black females (Fig. 29) highlighted that DJD in the upper peripheral region was higher in black females than black males for the TMJ (black females = 1,13; black males = 0,80), shoulder (black females = 2,24; black males = 2,08), elbow (black females = 2,04; black males = 1,94), and fingers (black females = 1,93; black males = 1,87) joints; apart from the wrist (black females = 1,49; black males = 1,65) joint. The lower peripheral region is evenly split between the two groups, with DJD in the hip (black females = 1,91; black males = 1,97) and knee (black females = 1,76; black males = 1,77) joints being more prevalent in black males, and DJD in the ankle (black females = 1,53; black males = 1,44) and toe (black females = 1,56; black males = 1,31) joints being more prevalent in black females.

Across the entire axial region, black males have a mean severity rate in the cervical (black females = 0,91; black males = 1,01), thoracic (black females = 0,60; black males = 0,67) and lumbar (black females = 1,56; black males = 1,80) vertebral joints.

Welch's t-tests were run to determine if there were any joints which showed a significant difference. The TMJ ($p = 0,048$) was the only joint that showed a significant difference between black males and females where black females had significantly higher mean severity scores.

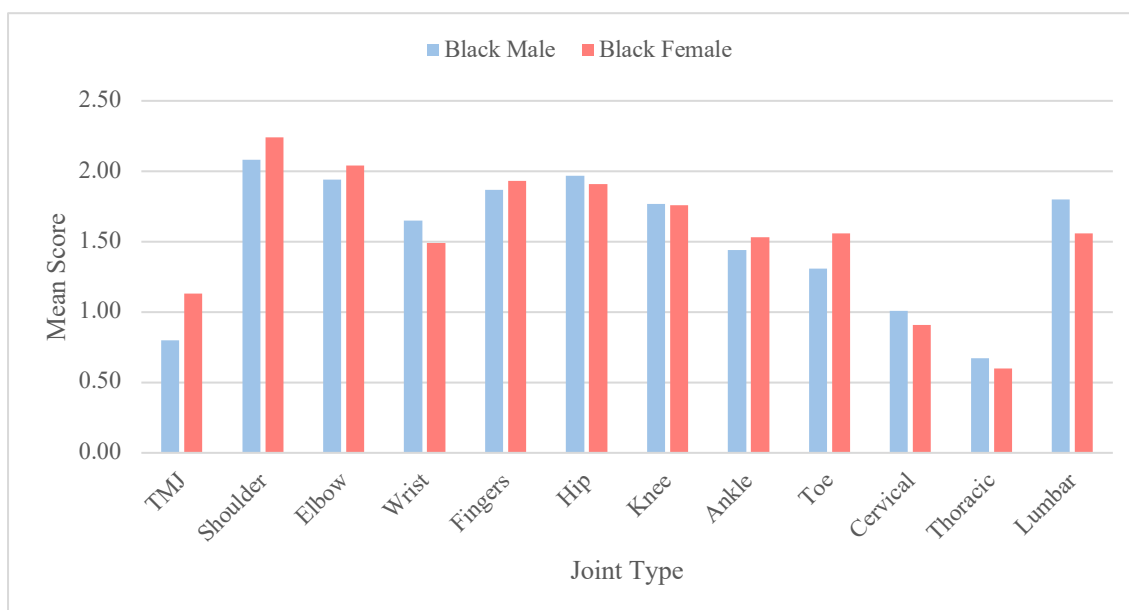


Figure 29. Comparing black male and black female DJD scores

Across the comparison between black females and white females (Fig. 30), white females presented higher DJD scores in almost all peripheral joints, specifically TMJ (black females = 1,13; white females = 1,59), shoulder (black females = 2,24; white females = 2,33), wrist (black females = 1,49; white females = 1,63), fingers (black females = 1,93; white females = 2,00), hip (black females = 1,91; white females = 2,22), knee (black females = 1,79; white females = 1,81), and toe (black females = 1,56; white females = 1,85); except for the elbow (black females = 2,04; white females = 1,52) and ankle (black females = 1,53; white females = 1,04) joints where black females presented with higher mean scores.

The mean DJD scores in the axial joints were all dominated by the white female cohort, with the cervical (black females = 0,91; white females = 1,63), thoracic (black females = 0,60;

white females = 1,48), lumbar (black females = 1,56; white females = 1,85) vertebral joints all indicating a higher mean score.

Welch's t-tests were run to determine if there were any joints which showed a significant difference. The DJD scores for the hip ($p = 0,041$), cervical ($p = 0,009$), and thoracic vertebral joints ($p = 0,001$) in white females were significantly higher than those in black females. In black females, the DJD scores were significantly higher than in white females, in the elbow ($p = 0,002$) and ankle ($p = 0,004$) joints. The TMJ although showing large mean severity score differences was not quite statistically significant with $p = 0,072$.

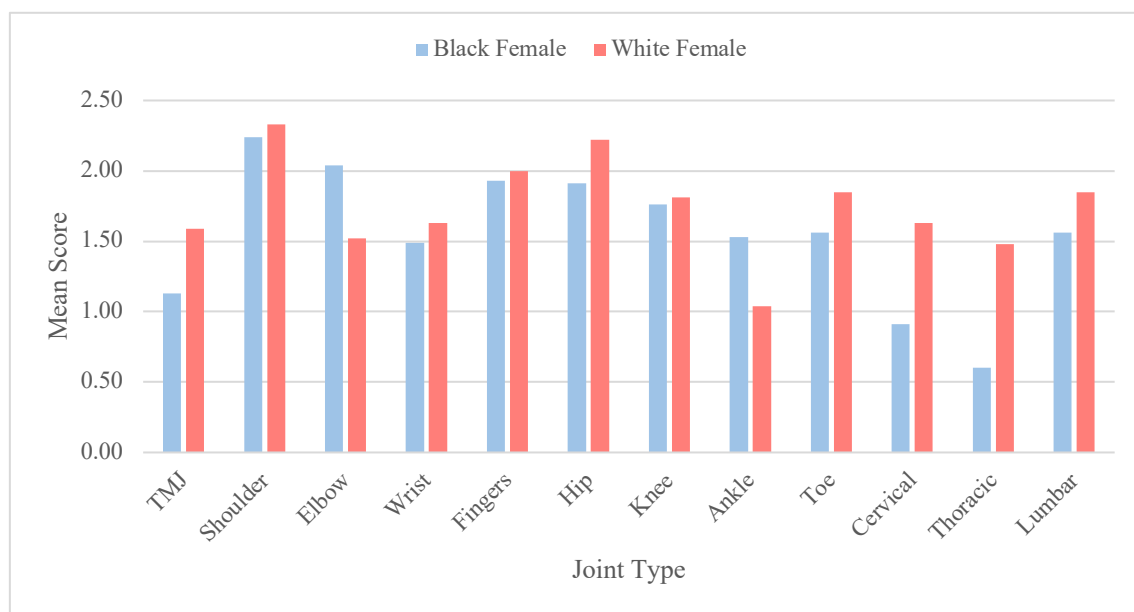


Figure 30. Comparing black female and white female DJD scores

5.3.5. Age

Table 13 provides a visual display of the changes of DJD with increasing age. For almost all of the joints, there is an expected gradual increase in the mean DJD severity scores with age. Two exceptions were the elbow and ankle joints, both of which more often presented with higher mean severity scores in younger to middle-aged adult individuals (35 – 54 years; 55 – 74 years). The information that follows in the sections below is obtained from Table 13.

The age group 35 – 54 years had the highest mean severity scores presenting in the elbow (1,96) and shoulder (1,78), and the lumbar (1,20) vertebra in the axial skeleton. All of the scores started off as being lower in this group as opposed to others, except for the elbow, when compared across the older age group. This may be an indication that age was not the

only definitive influence here. Lastly, the elbow and fingers are the only joints where all individuals in the cohort showed signs of DJD.

The next age group (55 – 74 years) had the highest mean severity scores in the shoulder (2,37) and hip (2,13), and the lumber (1,99) vertebral joints for the axial skeleton. Of all the age cohorts assessed in this study the 55-74-year cohort presented with the highest mean severity scores with the elbow (1,96) and ankle (1,54). This is an interesting result suggesting that something other than age may be influencing the DJD progression in these joints. In Table 13 below, the shoulder, elbow, hip, and knee joints all showed signs of some form of DJD.

The oldest age group (75 – 94 years) presented with the highest mean scores for the shoulder (2,48) and hip (2,19), and the lumber (2,00) vertebral joints in the axial skeleton. This age group had the overall highest mean severity scores for the shoulder (2,48), the wrist (1,71), the fingers (2,10), the hip (2,19), the knee (1,83), and the toe (1,74) joints in the peripheral skeleton. The following axial joints also presented with the overall highest mean severity scores across the different age cohorts, the TMJ (1,38), cervical (1,69), thoracic (1,17) and lumber (2,00). Lastly, the shoulder, elbow, wrist, fingers, hip, and ankle joints in this group of the oldest individuals all showed signs of DJD as no severity scores of 0 were observed.

A Welch's t-test indicated higher significant mean severity score differences between the younger (35 – 54 years) and middle-aged (55 – 74 years) individuals for the shoulder ($p = 0,0001$), hip ($p = 0,013$), cervical ($p = 0,006$), thoracic ($p = 0,0005$) and lumbar ($p = 0,0002$) vertebrae where the latter had a statistically higher significance. A t-test was run for the middle (55 – 74 years) and older (75 – 94 years) ages and showed higher significance for the cervical vertebra ($p = 0,02$) where the latter had a statistically higher significance. Lastly, t-tests were run between the younger (35 – 54 years) and the older-aged (75 – 94 years) with the latter being statistically significantly higher for the TMJ ($p = 0,018$), shoulder ($p = 0,0001$), finger ($p = 0,02$), hip ($p = 0,002$) joints and the cervical ($p = 0,0001$), thoracic ($p = 0,004$) and the lumbar ($p = 0,0007$) vertebral joints.

Table 13. DJD scores across age differences

	Age 35 – 54							Age 55 - 74							Age 75 - 94						
Joint Type	Sample (N)	Percentage Score (%)					Mean Severity Score	Sample (N)	Percentage Score (%)					Mean Severity Score	Sample (N)	Percentage Score (%)					Mean Severity Score
		0	1	2	3	4			0	1	2	3	4			0	1	2	3	4	
Upper Peripheral Skeleton																					
TMJ	49	42,86	30,61	22,45	4,08	-	0,88	70	31,43	35,71	24,29	8,57	-	1,10	31	19,35	32,26	38,71	9,68	-	1,39
Shoulder	49	4,08	34,69	40,82	20,41	-	1,78	70	0,00	14,29	34,29	51,43	-	2,37	31	0,00	9,68	32,26	58,06	-	2,48
Elbow	49	0,00	26,53	51,02	22,45	-	1,96	70	0,00	27,14	50,00	22,86	-	1,96	31	0,00	38,71	51,61	9,68	-	1,71
Wrist	49	2,04	55,10	38,78	4,08	-	1,45	70	1,43	38,57	52,86	7,14	-	1,66	31	0,00	35,48	58,06	6,45	-	1,71
Fingers	49	0,00	38,78	48,98	12,24	-	1,73	70	2,86	17,14	62,86	17,14	-	1,94	31	0,00	16,13	58,06	25,81	-	2,10
Lower Peripheral Skeleton																					
Hip	48	2,08	33,33	50,00	14,58	-	1,73	70	0,00	18,57	47,14	31,43	-	2,13	31	0,00	9,68	61,29	29,03	-	2,19
Knee	49	10,20	32,65	34,69	22,45	-	1,69	70	0,00	32,86	28,57	30,00	-	1,80	30	6,67	26,67	43,33	23,33	-	1,83
Ankle	49	4,08	61,22	32,65	2,04	-	1,33	70	5,71	50,00	28,57	15,71	-	1,54	31	0,00	51,61	35,48	0,00	-	1,23
Toe	49	14,29	42,86	36,73	6,12	-	1,35	70	10,00	41,43	38,57	10,00	-	1,49	31	19,35	25,81	16,13	38,71	-	1,74
Axial Skeleton																					
Cervical	49	65,31	12,24	16,33	6,12	0,00	0,63	70	35,71	22,86	31,43	10,00	0,00	1,16	31	19,35	9,68	58,06	9,68	3,23	1,68
Thoracic	49	73,47	20,41	4,08	0,00	2,04	0,37	70	45,71	22,86	14,29	10,00	7,14	1,1	30	40,00	30,00	10,00	13,33	6,67	1,17
Lumbar	49	42,86	14,29	24,49	16,33	2,04	1,20	70	10,00	18,57	37,14	31,43	2,86	1,99	30	3,33	20,00	50,00	26,67	0,00	2,00

- Denotes that this section had no individuals present

Pearson Correlation Coefficient tests were performed to determine if there is a relationship between age and the severity of DJD. As can be seen in Appendix A, figures 40 to 48, all joints indicate a positive relationship. The results for all tests indicated a weak, but positive, correlation for the shoulder ($r = 0.3063$), wrist ($r = 0.1205$), finger ($r = 0.1775$), hip ($r = 0.1248$), knee ($r = 0.046$), toe ($r = 0.1501$) joints and the cervical ($r = 0.34$), thoracic ($r = 0.2295$) and lumbar ($r = 0.2877$) vertebral joints. The shoulder and axial skeletal joints indicate a higher correlation but according to the criteria set out by Schober *et al.* (2018) this is still classified as a weak (0.1 – 0.39) to negligible (0.0 – 0.1) correlation overall. This can be confirmed by Table 13 and the mean average scores increasing with age for these specific joints.

The TMJ was subjected to a Pearson Correlation Coefficient test as the white individuals presented with substantially higher mean TMJ scores. To identify if these scores were related to age and if they differed from the black population affinity this test was conducted to gather a deeper understanding. The results showed a negative correlation for the white population affinity with a score of $r = -0.0087$, indicating that there was a negligible correlation (Figs. 30-31) (Schober *et al.*, 2018). The black population affinity offered a positive correlation with a score of $r = 0.1336$, indicating a weak positive correlation. The elbow and ankle joints do not appear to show this same age-related trend as seen in Table 12 above, with the younger adult ages showing higher DJD mean scores than the older adult age category. Again, a Pearson Correlation Coefficient was run between population groups (Figs. 31-36). For the white sample, both the wrist and hip indicated that there was a negative correlation with a score of $r = -0.2158$ and $r = -0.191$, respectively. As per the categories set out by Schober *et al.* (2018), both would be classified as weak. The black population had both negative and positive correlations with the elbow scoring $r = -0.0096$ and the ankle scoring $r = 0.046$, respectively. Schober *et al.* (2018), would categorise both of these scores as being negligent.

White Population Affinity

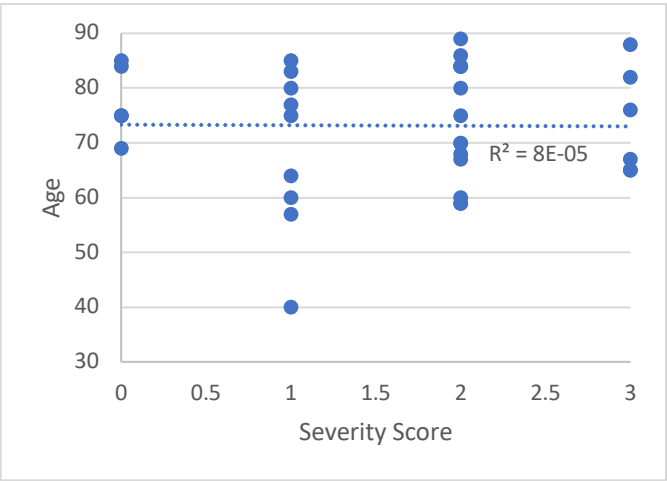


Figure 31. Age vs. DJD score correlation for the TMJ

Black Population Affinity

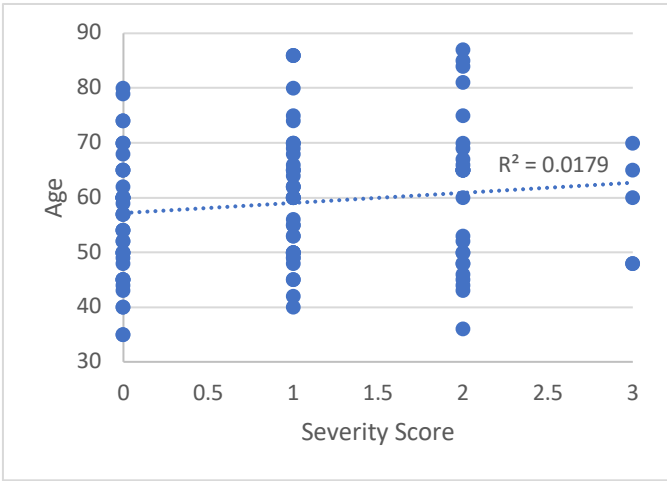


Figure 32. Age vs. DJD score correlation for the TMJ

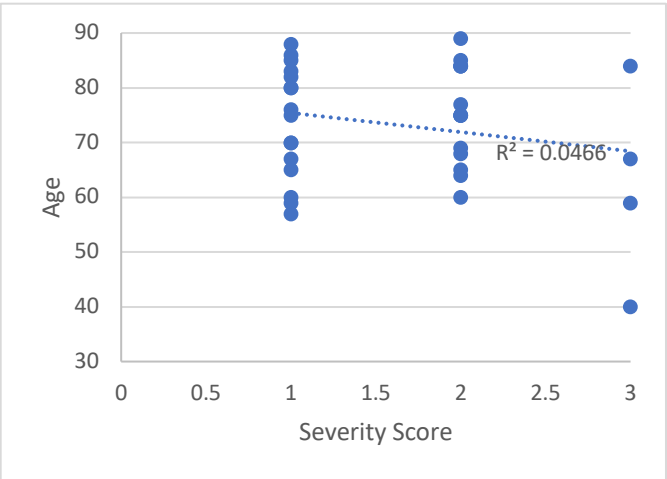


Figure 33. Age vs. DJD score correlation for the elbow joint

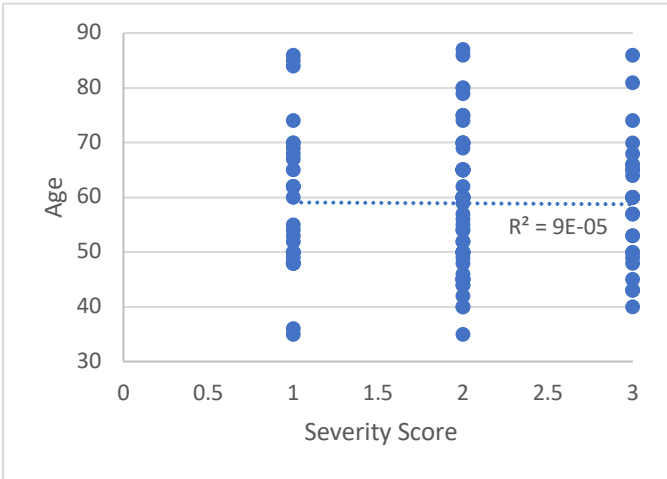


Figure 34. Age vs. DJD score correlation for the elbow joint

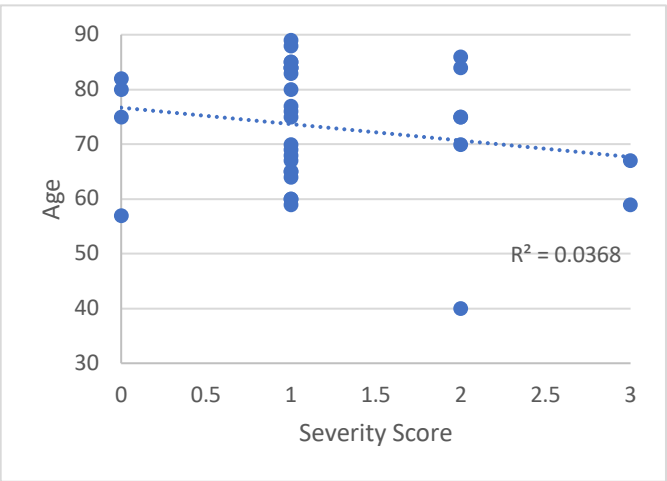


Figure 35. Age vs. DJD score correlation for the ankle joint

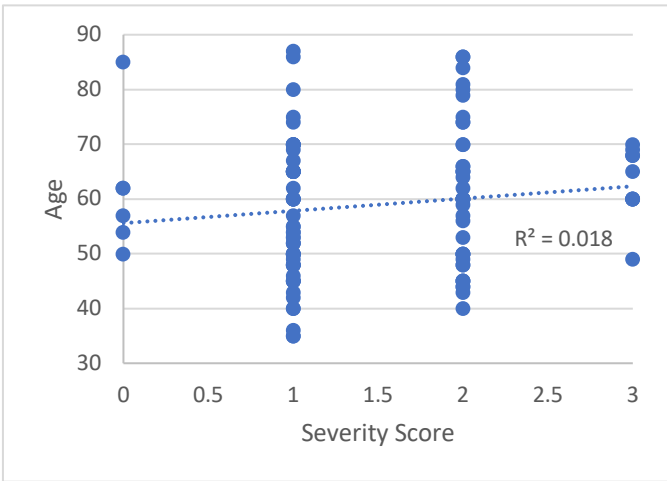


Figure 36. Age vs. DJD score correlation for the ankle joint

5.4. Activities of Daily Living Impairment

5.4.1. Overall

The ADLs were converted from the exiting DJD scores and this is represented in Table 4 in the methods section. Each of the joints were divided into particular ADLs, based on the movement each joint would inhibit when performing these specific activities. An overview of all ADLs is represented in Table 14. Talking represented the lowest ADL mean score of 0,41, indicating that most of the individuals would show no symptoms (66%) or some pain (26.67%) when attempting to complete this ADL. Over 50% of individuals may have shown signs of severe pain or limitations in mobility when attempting to transfer themselves or when walking as they presented with ADL scores of 1,47 and 1,44, respectively. Posture changes presented with the third highest mean ADL score (1,21) with between 36,67% and 31,33% of individuals possibly suffering from pain to severe pain and immobility, whereas 7,33% presented with the possible complete loss of mobility of this ADL. Assessing at the individual movements associated with posture changes in the vertebral column bending was most often affected with between 35,57% and 25,50% of individuals possibly having suffered pain to severe pain/mobility reduction respectively, with a mean severity score of 0,93. However, the inability to produce any mobility when attempting the twisting ADL was the most common postural change in the posture ADL (5,37%).

Table 14. ADL scores across the overall sample

ADL Type	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		None	Pain	Severe Pain/ Mobility Reduction	Immobility	
Transferring	150	6,00	41,33	52,67	-	1,47
Eating	150	5,33	53,33	41,33	-	1,36
Talking	150	66,00	26,67	7,33	-	0,41
Object Manipulation	150	25,33	57,33	17,33	-	0,92
Walking	150	6,67	42,67	50,67	-	1,44
Posture Changes	150	24,67	36,67	31,33	7,33	1,21
- Head Rotation	150	58,67	32,00	8,67	0,67	0,51
- Twisting	149	77,18	10,07	7,38	5,37	0,41
- Bending	149	36,91	35,57	25,50	2,01	0,93

- Denotes that this section had no individuals present

5.4.2. Sex

Table 15 highlights differences between ADLs in the different sexes. Over half of the sample for males could have presented with severe pain/mobility reduction for the walking ADL and in females this was found in both the transferring and walking ADLs. The talking ADL was the least impaired with 78% of males and 53% of females showing no effects when completing this ADL. Lastly, in terms of posture changes, the twisting ADL was the activity that suffered the most from complete immobility between both males (6,49%) and females (4,17%); however, both were below 10% of their respective samples.

Overall, females presented with higher mean ADL severity scores when it came to transferring (males = 1,40; females = 1,54), eating (males = 1,29; females = 1,43), talking (males = 0,29; females = 0,60), object manipulation (males = 0,60; females = 0,99), walking (males = 1,41; females = 1,47) and head rotation (males = 0,44; females = 0,60). Whereas males showed greater difficulty when completing the twisting (males = 0,42; females = 0,40) and bending (males = 1,01; females = 0,83) ADLs.

A Welch's t-test was conducted to determine any statistical differences. Females presented with significantly higher mean severity scores over males for the talking ($p = 0,0016$) ADL. Whereas males had a significantly higher mean severity score over females for the bending ($p = 0,006$) ADL.

Table 15. Comparing ADLs between males and females

ADL Type	Males						Females					
	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		0	1	2	3			0	1	2	3	
Transferring	78	7,69	44,87	47,44	-	1,4	72	4,17	37,50	58,33	-	1,54
Eating	78	7,69	55,13	37,18	-	1,29	72	2,78	51,39	45,83	-	1,43
Talking	78	78,21	19,23	2,56	-	0,29	72	52,78	34,72	12,50	-	0,6
Object Manipulation	78	29,49	55,13	15,38	-	0,86	72	20,83	59,72	19,44	-	0,99
Walking	78	8,97	41,03	50,00	-	1,41	72	4,17	44,44	51,39	-	1,47
Posture Changes	78	25,64	34,62	33,33	6,41	1,21	72	23,61	38,89	29,17	8,33	1,22
- Head Rotation	78	62,82	30,77	6,41	0,00	0,44	72	54,17	33,33	11,11	1,39	0,6
- Twisting	77	77,92	9,09	6,49	6,49	0,42	72	76,39	11,11	8,33	4,17	0,4
- Bending	77	35,06	29,87	33,77	1,30	1,01	72	38,89	41,67	16,67	2,78	0,83

- Denotes that this section had no individuals present

5.4.3. Population Affinity

Table 16 below highlights the differences in mean ADL scores between black and white individuals in the sample. The black population cohort indicated a 50% and 47% severe pain/mobility reduction effect on the transferring and walking ADLs, respectively. This differs from the white affinity group where the walking (62%) was higher than transferring (59%) ADLs for severe pain/mobility reduction. The white cohort showed that the talking ADL had 41% where individuals had no symptoms, in comparison to the black cohort which was much higher at 73%. Lastly, the postural changes, specifically the twisting ADL received the highest immobility scores with the white cohort at 9% and the black cohort at 4%.

The results indicated that the white individuals had higher mean ADL scores for transferring (black = 1,44; white = 1,56), eating (black = 1,34; white = 1,44), talking (black = 0,31; white = 0,76), object manipulation (black = 0,91; white = 0,97), walking (black = 1,40; white = 1,59), head rotation (black = 0,46; white = 0,71) and twisting (black = 0,28; white = 0,85). Whereas the black individuals showed higher mean ADL scores for bending (black = 0,95; white = 0,85).

Welch's t-test results indicated that the talking ($p = 0,0001$) and twisting ($p = 0,0004$) ADLs were significantly higher in the white individuals compared to the black. None of the other differences were statistically significant.

Table 16. Comparing ADLs between black and white population affinities

	Black Population Affinity						White Population Affinity					
ADL Type	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		0	1	2	3			0	1	2	3	
Transferring	116	6,90	42,24	50,00	-	1,44	34	2,94	38,24	58,82	-	1,56
Eating	116	6,90	52,59	40,52	-	1,34	34	0,00	55,88	44,12	-	1,44
Talking	116	73,28	22,41	4,31	-	0,31	34	41,18	41,18	17,65	-	0,76
Object Manipulation	116	26,72	56,03	17,24	-	0,91	34	20,59	61,76	17,65	-	0,97
Walking	116	7,76	44,83	47,41	-	1,4	34	2,94	35,29	61,76	-	1,59
Posture Changes	116	28,45	34,48	31,03	6,03	1,15	34	11,76	44,12	32,35	11,76	1,44
- Head Rotation	116	62,93	28,45	8,62	0,00	0,46	34	44,12	44,12	8,82	2,94	0,71
- Twisting	115	84,35	7,83	3,48	4,35	0,28	34	52,94	17,65	20,59	8,82	0,85
- Bending	115	38,26	31,30	27,83	2,61	0,95	34	32,35	50,00	17,65	0,00	0,85

- Denotes that this section had no individuals present

5.4.4. Population Affinity and Sex

a. White Males

As with the DJD sample, the ADL sample for white males is too small for statistical comparisons. Descriptive methods were still used to identify any possible trends and are represented in Table 17. Walking presented with the highest ADL score (1.86) with 85,71% of the individuals possibly having had severe pain and mobility reduction. This ADL was closely followed by transferring with a mean severity score of 1,71 and 71,43% of individuals possibly having suffered from severe pain and mobility reduction.

There were no individuals that presented with a score of 0 or “None” for transferring, eating, and walking ADLs, indicating that every individual in the white male sample had some form of difficulty when completing these ADLs. When assessing at posture-related ADLs, 42,86% of individuals could have suffered from severe pain and mobility reduction. The specific posture-related ADL that was most severely affected was twisting with a mean severity score of 1,29 with 14,29% of these individuals probably suffering from immobility.

Table 17. ADL scores across the white male cohort

ADL Type	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		None	Pain	Severe Pain/ Mobility Reduction	Immobility	
Transferring	7	0,00	28,57	71,43	-	1,71
Eating	7	0,00	57,14	42,86	-	1,43
Talking	7	28,57	71,43	0,00	-	0,71
Object Manipulation	7	28,57	71,43	0,00	-	0,71
Walking	7	0,00	14,29	85,71	-	1,86
Posture Changes	7	14,29	28,57	42,86	14,29	1,57
- Head Rotation	7	85,71	14,29	0,00	0,00	0,14
- Twisting	7	28,57	28,57	28,57	14,29	1,29
- Bending	7	42,86	28,57	28,57	0,00	0,86

- Denotes that this section had no individuals present

b. Black Males

Black males received the same mean score of 1,37 for both the transferring and walking ADLs (Table 18). Following the same trend as seen with the white male cohort.

Just under 50% of these individuals showed the possibility of inhibition of transferring and walking due to pain or slight mobility issues. Between 35,21 and 32,39% of individuals were noted to have had possible pain or severe pain and mobility reduction during posture changes. Of the three posture changes, bending received the highest mean score (1,03), with only one-third of the cohort having no symptoms. Even though a large proportion of the individuals in this subgroup most likely did not experience any pain (82,86%) when engaging in twisting activities 5,71% of this subgroup experienced immobility for the same ADL.

Table 18. ADL scores across the black male cohort

ADL Type	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		None	Pain	Severe Pain/ Mobility Reduction	Immobility	
Transferring	71	8,45	46,48	45,07	-	1,37
Eating	71	8,45	54,93	36,62	-	1,28
Talking	71	83,10	14,08	2,82	-	0,2
Object Manipulation	71	29,58	53,52	16,90	-	0,87
Walking	71	9,86	43,66	46,48	-	1,37
Posture Changes	71	26,76	35,21	32,39	5,63	1,17
- Head Rotation	71	60,56	32,39	7,04	0,00	0,46
- Twisting	70	82,86	7,14	4,29	5,71	0,33
- Bending	70	34,29	30,00	34,29	1,43	1,03

- Denotes that this section had no individuals present

c. Black Females

In the black female cohort (Table 19), transferring (mean severity score = 1,56) and walking (mean severity score = 1,44) are the ADLs which appear to have been the most impacted.

This trend is consistent with the above white and black male cohort.

Exactly 60% and just under 50% of black females received a severity score where there may have been symptoms of severe pain and mobility reduction when completing the transferring and walking ADLs, respectively. In terms of posture changes, bending received the highest mean score of 0,82 with over 66% of the cohort experiencing symptoms including anything between pain to immobility when attempting to complete this ADL.

Table 19. ADL scores across the black female cohort

ADL Type	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		None	Pain	Severe Pain/ Mobility Reduction	Immobility	
Transferring	45	4,44	35,56	60,00	-	1,56
Eating	45	4,44	48,89	46,67	-	1,42
Talking	45	57,78	35,56	6,67	-	0,49
Object Manipulation	45	22,22	60,00	17,78	-	0,96
Walking	45	4,44	46,67	48,89	-	1,44
Posture Changes	45	31,11	33,33	28,89	6,67	1,11
- Head Rotation	45	66,67	22,22	11,11	0,00	0,44
- Twisting	45	86,67	8,89	2,22	2,22	0,2
- Bending	45	44,44	33,33	17,78	4,44	0,82

- Denotes that this section had no individuals present

d. White Females

In the white female cohort (Table 20), transferring and walking received the highest mean ADL scores, with both receiving a score of 1,52. This is a trend that is largely present in all the above cohorts.

Over 50% of this group received the scores for signs of severe pain and/or mobility loss for the transferring and walking ADLs. Posture changes showed slightly different trends than those above, with head rotation and bending with the highest ADL mean scores of 0,85 for both. Even though the twisting ADL presented with the lowest mean severity score (0.74) 7.41% of the individuals in this group potentially suffered from immobility when attempting to complete this task.

Table 20. ADL scores across the white female cohort

ADL Type	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		None	Pain	Severe Pain/ Mobility Reduction	Immobility	
Transferring	27	3,70	40,74	55,56	-	1,52
Eating	27	0,00	55,56	44,44	-	1,44
Talking	27	44,44	33,33	22,22	-	0,78
Object Manipulation	27	18,52	59,26	22,22	-	1,04
Walking	27	3,70	40,74	55,56	-	1,52

Table 20. ADL scores across the white female cohort

Posture Changes	27	11,11	48,15	29,63	11,11	1,41
- Head Rotation	27	33,33	51,85	11,11	3,70	0,85
- Twisting	27	59,26	14,81	18,52	7,41	0,74
- Bending	27	29,63	55,56	14,81	0,00	0,85

- Denotes that this section had no individuals present

e. Population Affinity and Sex Comparisons

Figure 37 compares mean scores between black males and females and white females for all ADLs. A Welch's t-test was run across all three sub-samples and mean severity scores for all ADLs. Black females (mean severity = 0,49) showed a statistically significant ($p = 0,0049$) higher mean severity score for the talking ADL compared to black males (mean severity = 0,2). Whereas white females show a higher mean severity score (0,78) against only black males (0,2) with $p = 0,0001$ for the talking ADL. White females also presented with statistically significantly higher mean severity scores for head rotation (mean severity = 0,85; $p = 0,023$) and twisting (mean severity = 0,74; $p = 0,0057$) posture changes when compared to black females (head rotation mean severity = 0,44; twisting mean severity = 0,2). Similarly, white females also presented with statistically significantly higher mean severity scores for head rotation ($p = 0.012$) and twisting ($p = 0.04$) when compared to black males (head rotation mean severity = 0,46; twisting severity score = 0,33).

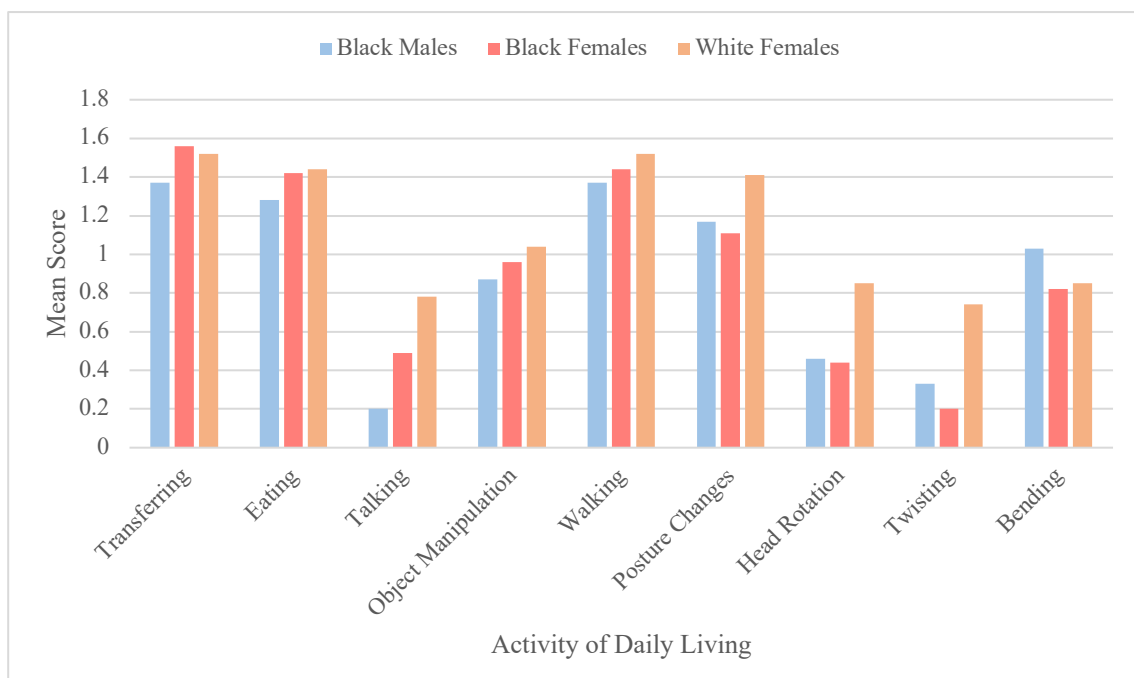


Figure 37. Comparing black male, black female and white female ADL scores

5.5.Socio-economic Status

The data reported in Table 21 indicated that most of the individuals who were identified as coming from a lower SES fell in the black population affinity group. Whereas the higher SES was mainly from a white population affinity. With these samples, the lower SES had a mean age of 58,89 years and the higher SES had a mean age of 72,36 years, with the substantial differences in these SES cohorts there is a high chance that data may be skewed due to age.

Within the peripheral skeleton there are slight differences represented with the lower SES group presenting with higher mean severity scores for the elbow (lower SES = 1,98; higher SES = 1,67), wrist (lower SES = 1,61; higher SES = 1,58), knee (lower SES = 1,78; higher SES = 1,74), ankle (lower SES = 1,46; higher SES = 1,22) and lumbar (lower SES = 1,74; higher SES = 1,69) vertebral joints. The remaining joints; TMJ (lower SES = 0,94; higher SES = 1,56), shoulder (lower SES = 2,14; higher SES = 2,39), fingers (lower SES = 1,89; higher SES = 1,94), hip (lower SES = 1,89; higher SES = 2,22), and toe (lower SES = 1,39; higher SES = 1,81) were higher in the higher SES cohort.

The axial skeleton highlighted that the cervical (lower SES = 0,92; higher SES = 1,44) and thoracic (lower SES = 0,73; higher SES = 1,33) vertebral joints mean score were higher in the higher SES cohort.

Table 21. DJD scores across higher and lower socio-economic status sample

	Lower SES							Higher SES						
Joint Type	Sample (N)	Percentage Score (%)					Mean Severity Score	Sample (N)	Percentage Score (%)					Mean Severity Score
		0	1	2	3	4			0	1	2	3	4	
Upper Peripheral Skeleton								Upper Peripheral Skeleton						
TMJ	114	36,84	36,84	21,93	4,39	-	0,94	36	19,44	22,22	41,67	16,67	-	1,56
Shoulder	114	1,75	21,93	36,84	39,47	-	2,14	36	0,00	13,89	33,33	52,78	-	2,39
Elbow	114	0,00	24,56	52,63	22,81	-	1,98	36	0,00	44,44	44,44	11,11	-	1,67
Wrist	114	1,75	41,23	51,75	5,26	-	1,61	36	0,00	50,00	41,67	8,33	-	1,58
Fingers	114	0,88	26,32	55,26	17,54	-	1,89	36	2,78	16,67	63,89	16,67	-	1,94
Lower Peripheral Skeleton								Lower Peripheral Skeleton						
Hip	113	0,88	25,66	49,56	23,89	-	1,89	36	0,00	8,33	61,11	30,56	-	2,22
Knee	114	8,77	30,70	34,21	26,32	-	1,78	36	8,57	34,29	31,43	25,71	-	1,74
Ankle	114	5,26	50,88	35,96	7,89	-	1,46	36	11,11	63,89	16,67	8,33	-	1,22
Toe	114	12,28	44,74	34,21	8,77	-	1,39	36	16,67	19,44	30,56	33,33	-	1,81
Axial Skeleton								Axial Skeleton						
Cervical	114	47,37	15,79	28,07	8,77	0,00	0,92	36	25,00	19,44	44,44	8,33	2,78	1,44
Thoracic	113	61,06	20,35	8,85	4,42	5,31	0,73	36	30,56	33,33	13,89	16,67	5,56	1,33
Lumbar	113	23,01	13,27	32,74	28,32	2,65	1,74	36	8,33	30,56	44,44	16,67	0,00	1,69

- Denotes that this section had no individuals present

To identify how much age is playing a role in the data presented above, age was controlled within the different SES groups and displayed in Figure 38. The age cohort that was selected for comparison was all individuals between 55 – 75 years as both sub-groups presented sufficient numbers of individuals between these ages.

The peripheral skeleton showed that the lower SES indicated higher DJD in various joint types, namely: the shoulder (lower SES = 2,39; higher SES = 2,24), elbow (lower SES = 2,02; higher SES = 1,71), fingers (lower SES = 2,02; higher SES = 1,88), knee (lower SES = 1,83; higher SES = 1,69) and ankle (lower SES = 1,58; higher SES = 1,35) joints. The TMJ (lower SES = 0,98; higher SES = 1,47), wrist (lower SES = 1,69; higher SES = 1,71), hip (lower SES = 2,10; higher SES = 2,24) and toe (lower SES = 1,39; higher SES = 1,82) joints were noted as higher in the higher SES group.

The axial skeleton highlighted the lower SES indicated a higher DJD mean severity score for the lumbar (lower SES = 2,10; higher SES = 1,71) vertebral joint. The higher SES indicated a higher DJD for the cervical (lower SES = 1,20; higher SES = 1,41) and thoracic (lower SES = 1,00; higher SES = 1,41) vertebral joints.

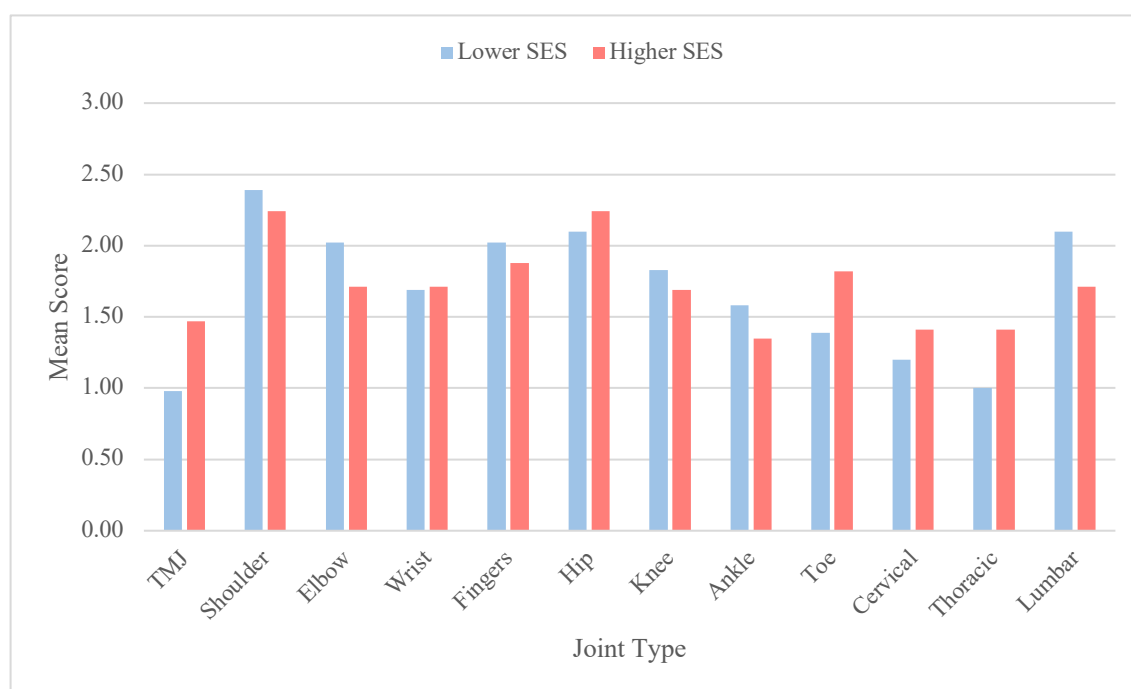


Figure 38. Comparing age controlled higher and lower SES groups' DJD mean severity scores

The data presented in Table 21 was then converted into ADL scores and presented in Table 22 below. Individuals assigned to the lower SES indicated higher mean severity scores for the ADLs in transferring (1,61), object manipulation (1,02) and posture change, specifically bending (1,21). Higher SES individuals indicated higher mean severity scores for ADLs in walking (1,64) and talking (0,65). The lower SES cohort indicated that (8,06%) and (3,23%) of individuals had complete mobility loss in twisting and bending activities, respectively. Whereas higher SES indicated that 7,14% of individuals had complete mobility loss when attempting head rotation activities.

Welch's t-test was conducted between the lower and higher SES groups where age was controlled for. The results showed that there was no statistically significant difference across the transferring ($p = 0,337$), eating ($p = 0,316$), talking ($p = 0,563$), object manipulation ($p = 0,936$), walking ($p = 0,481$), head rotation ($p = 0,97$) and twisting ($p = 0,93$) ADLs for this sample group. The bending ADL was statistically significant where the lower SES showed a higher average mean compared to the higher SES ($p = 0,009$).

Table 22. ADL scores across a controlled higher and lower socio-economic status sample

ADL Type	Lower SES (Controlled for age 55-75)						Higher SES (Controlled for age 55-75)					
	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score	Sample (N)	Percentage Score of ADL Symptoms (%)				Mean Severity Score
		0	1	2	3			0	1	2	3	
Transferring	62	3,23	32,26	64,52	-	1,61	14	7,14	42,86	50,00	-	1,43
Eating	62	4,84	46,77	48,39	-	1,44	14	0,00	71,43	28,57	-	1,29
Talking	62	69,35	30,65	8,06	-	0,39	14	57,14	35,71	7,14	-	0,65
Object Manipulation	62	17,74	62,90	19,35	-	1,02	14	21,43	57,14	21,43	-	1,00
Walking	62	6,45	33,87	59,68	-	1,53	14	0,00	35,71	64,29	-	1,64
Posture Changes	62	12,90	32,26	45,16	9,68	1,54	14	28,57	42,86	21,43	7,14	1,07
- Head Rotation	62	54,84	32,26	12,90	0,00	0,58	14	57,14	35,71	0,00	7,14	0,57
- Twisting	62	69,35	14,52	8,06	8,06	0,55	14	64,29	14,29	21,43	0,00	0,57
- Bending	62	22,58	37,10	37,10	3,23	1,21	14	42,86	50,00	7,14	0,00	0,64

- Denotes that this section had no individuals present

6. DISCUSSION

6.1. Reliability and Repeatability

The scoring methodology used in this research project was a combination of various other tools used to identify and quantify the frequency and severity of DJD across axial and peripheral joints within the skeletal system (Kilgore, 1985; Buikstra & Ubelaker, 1994; Rojas-Sepúlveda *et al.*, 2008; Waldron, 2009). A new scoring method incorporating aspects of these existing methods was therefore employed in this study. Results from the intra-observer repeatability suggested an almost perfect agreement for both axial ($k = 0.917$, $p < 0.001$) and peripheral joints ($k = 0.942$, $p < 0.001$) showcasing that this method is repeatable and reliable. Slightly lower values were obtained for inter-observer repeatability for the axial ($k = 0.626$, $p < 0.001$) and peripheral joints ($k = 0.627$, $p < 0.001$); however, these results were still deemed to be of moderate agreement (McHugh, 2012). Given the level of experience required in utilising this method, the lower inter-observer results are to be expected. It is therefore advisable that should this method be employed in future studies the researcher first familiarise themselves with the scoring method. This is true of most morphoscopic scoring methods (Lesciotto & Doershuk, 2018; Henson *et al.*, 2020).

The results from the intra- and inter-observer repeatability also showcased the importance of utilising region-specific scoring criteria. Both raters indicated a higher agreement score for peripheral joints (intra = 0,942 and inter = 0,627), as opposed to the axial (intra = 0,917 and inter = 0,626) scores. What this could potentially indicate is creating a scoring method for each individual joint, or at the very least visual representations of each. Different joint types (hinge, ball-and-socket etc.) may present with different joint-specific representations of different DJD stages which could benefit from clearer criteria. This has never been included in any research to date and could provide beneficial knowledge in understanding the severity of DJD and how it manifests in joints over time.

The axial region performed with less agreement between both inter- and intra-observers, this was a surprising find given that there are very few ways in which the bone reacts to degeneration and the joints remain morphologically similar across the spine. A possibility for this could be due to there being less movement within these joints, meaning that there are more similar changes and therefore less of a distinction. This difficulty in differentiating

these scores combined with how they were calculated (taking the highest and most occurring score across each type of vertebral joint) leads to greater variation in what the outcome was.

6.2. Degenerative Joint Disease

One of the biggest reasons for conducting this research is the current lack of knowledge around DJD on skeletal populations. A study conducted by Usenbo *et al.* (2015) indicated that there is a major lack of information in South Africa regarding DJD studies. This meta-analysis indicated that only five studies had been conducted locally, and there have been very few additional papers added since the 1980s (Usenbo *et al.*, 2015). A greater number of studies, both within and outside of South Africa, should be done on full skeletal remains as this would provide a more complete picture of trends and further debates around age and functional stressors.

By assessing at the overall sample the impacts of DJD on specific joints can be seen. From the peripheral joints, the ball-and-socket joints of the shoulder and hip appear to be the most severely affected, both having the highest mean severity scores of 2,20 and 2,01, respectively. This study highlights their susceptibility to developing DJD and the rate of progression. No studies to date have been conducted to assessed if specific joint types would have an increased rate of DJD progression; however, what is known about types of joints that permit a wide range of movement, potentially causing more wear on these joints over others (Benjamin & McGonagle, 2013). If this is to be argued then it stands that where there is a greater range of motion, such as the shoulder over the hip (Juneja *et al.*, 2023), there should be greater DJD severity impacts which aligns with the results obtained herein. Other studies point to individual anatomical structure of a specific joint and body size as contributory degenerative causes (Weiss & Jurmain, 2007). These can include differences in knee alignment, hip socket depth and its combination with body mass (Weiss & Jurmain, 2007).

Assessing at the overview of joints presenting with DJD in the sample, there is a clear trend of the shoulder (2,20), hip (2,01), elbow (1,91) and/or finger (1,91) joints being the most highly impacted in relation to the mean severity score. This trend is not just found in the overall sample, but across most of the sub-groups as well, with some exceptions that will be discussed. What this consistency does highlight is that there may be a clear pattern to the

development of DJD across joints in the body based on information collected from skeletal remains.

The high degree of DJD scores in the hip found in this study is to be expected given that the hip is positively impacted by DJD as it is known to be a significant weight-bearing joint typically affected by osteoarthritic changes (Waldron, 1997). However, results obtained for the elbow and shoulder are interesting given that these joints are not typically regarded as weight-bearing and therefore should not be expected to present with such high scores, as observed in this study. However, a recent study by Kang *et al.*, (2023), the upper appendicular joints have also be affected by weight-bearing caused by muscles and associated gravitational pull on these joints. Unlike the hip and knee joints, the shoulder and elbow joint have a smaller surface area and as a result are more prone to develop pathology in response to the stresses placed on it (Kang *et al.*, 2023). It should, therefore, be noted that the joint type alone does not account for the full range of DJD seen, and that the general versatility of joints should be considered when assessing its susceptible to degenerative changes.

A study conducted on a sample from the 20th century, by Jurmain (1980), justifies this argument. This study was conducted on skeletal remains and using similar scoring criteria, but only observing the peripheral skeleton. In their study they report similar findings of the shoulder and hip being the two joints primarily involved with DJD, echoing the study conducted here. Unfortunately, within their study, no age ranges were given which ultimately limited the number of comparison that could be drawn. There is a later study published by Bridges (1991), with an agricultural sub-group in America during the 1900s which presented with the highest severity of DJD in the shoulders, elbow, and knee. Other studies on osteological remains draw the same conclusions, justifying the understanding that DJD may present observationally different in living vs deceased populations (Anderson, 1963; Miles 1966). This further substantiates the claim that joint severity and location can be somewhat predictable from skeletal analysis and could be beneficial when assessing at DJD specifically in forensic anthropological cases.

The results obtained from the axial skeleton shows fusion occurring, this was classified where vertebral joints were completely fused to neighbouring vertebral joints. Although

uncommon, ankylosis of the peripheral joints can occur (Kubiak *et al.*, 2005); however, this study did not observe any of these findings. Reasoning behind this could be the different types of joints being investigated. The peripheral joints in this study are defined as diarthrotic joints which are known to be freely moving, whereas in contrast, the axial joints are amphiarthrotic and consist of significantly less movement (O'Dwyer *et al.*, 2014). This limitation in joint movement may make these joints more susceptible to fusion. Literature on ankylosis, and DJD in general, often highlight that prevention methods involve keeping the joints as mobile as possible, which may be easier in joints with higher ranges of motion (O'Dwyer *et al.*, 2014).

The overall findings here highlight the cervical and lumbar vertebrae had the highest mean severity scores with 1,09 and 1,73, respectively. A South African study by Van Der Merwe *et al.* (2006), indicated that the cervical and lumbar vertebra were the most likely to be impacted by DJD. According to the overall sample given here, that same trend was seen here indicating a slightly systematic pattern of involvement within the vertebral column – particularly in the lumbar and cervical vertebra. Listi and Mahein (2012) conducted a study of osteophytosis and osteoarthritis across the entire axial skeleton and had a similar result where the cervical followed by lumbar joints were the most affected. Waldron (2009) offers an understanding as to why this may be a common interaction, compared to the thoracic vertebra these others have a greater range of movement. This promotes the argument here that the more movement in a joint, the greater the level of DJD that occurs at this site.

Nathan (1962) and Kim *et al.* (2012) attribute where osteophytes are present on the vertebral body to how close each vertebra is to the line of gravity – with peaks being at C5, T8 and L3 - 4 (Fig. 39 – recreated from Nathan, 1962: pg. 258). Thus these vertebra were subjected to the most stress and therefore produced the highest number of osteophytes across the spine, in order to regain some structural stability along the spine (Nathan, 1962). Vertebral osteophytes are often characterised by horizontal bone spurs or claws which curve towards the neighbouring disc. These develop primarily to maintain stability and to support the spinal structure during load bearing (Wong *et al.*, 2016). This could explain why the results indicated fusion across all the different vertebral joints types, with the cervical, thoracic, and lumbar vertebrae indicating a need to regain stability.

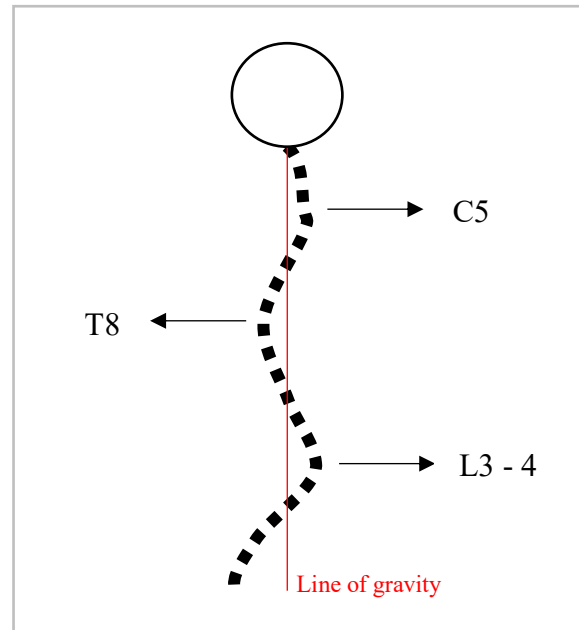


Figure 39. Figure indicating the line of gravity in relation to all vertebrae.

The vertebral bodies are known for playing a major role in the bearing of weight with over 80% of the load being sustained at this point (White & Panjabi, 1978). This combined with the understanding that the lumbar vertebrae are the joints supporting the entire upper peripheral and axial skeleton makes it extremely likely to suffer the most when assessing at the spinal joints (Waxenbaum *et al.*, 2023). This could stand to explain why there was such a marked increase in the mean severity score for the lumbar (1,73) vertebral joints as opposed to those of the cervical (1,09) and thoracic (0,87) across the overall sample.

Lastly, there were relatively higher frequency changes in the thoracic vertebra, in terms of score 4, with a percentage of 5,37%. Most studies conducted on DJD in the spine fail to include DISH as an additional causal factor for fusion. However, in terms of this study, it was difficult to exclude, especially in the earlier stages of manifestation. Research has further shown that DISH and osteoarthritis often co-occur, have similar aetiologies, and present with similar symptoms (e.g., pain and mobility impingement) and because of this have been included and will be examined deeper in the sections that follow (Rogers & Waldron, 2001; Sarzi-Puttini & Atzeni, 2004).

6.2.1. Sex Differences

Sex differences amongst DJD are slightly greater in females in the present study, with the ball-and-socket joints of the shoulder (2,28) and hip (2,03) receiving higher mean severity scores, as well as the finger (1,96), toe (1,67) and TMJ (1,31) joints. A meta-analysis from Srikanth *et al.* (2005) supports the understanding that females are largely more susceptible to DJD with results from over 68 journal articles worldwide reporting an increasing trend in females. A suggestion is that hormonal changes (specifically concerning a decline in oestrogen levels) at the time of menopause may lead to an increased prevalence of DJD (Nevitt & Felson, 1996; Neogi & Zhang, 2013). The understanding of this correlation is that with decreases in oestrogen levels, there is less ability to turnover articular cartilage leading to joint destruction (Karsdal *et al.*, 2012; Lou *et al.*, 2016).

However, the problem with this type of thinking is that it fails to take the roles of the different joint types into account. From the literature it is known that hinge joints such as the elbow, knee and ankle are structurally capable of supporting large amounts of force and aid in a lot of performance-based work (Gupton *et al.*, 2023). From this deduction, it could be considered that the more demanding, laborious, physical activity that the individual undergoes, the more impacted these joints may have been. The findings from this study support this inference with the elbow (1,96), knee (1,77) and ankle (1,46) all presenting with higher mean severity score in the male cohort.

Males presented with a higher mean severity score for the lumbar (1,77) vertebral joints as opposed to the female cohort. The study results from Van Der Merwe *et al.* (2006) support this finding with their study stating that DJD severity was more likely to be prevalent in males for both the cervical and lumbar vertebral joints. This was cited potentially due to males' robusticity, weight and association with strenuous activities throughout their lives, especially in individuals that engage in physical labour, such as mine workers (the study sample in this case). The justification behind DJD of this joint being more prevalent in males is suggested by Battié *et al.* (2004) to be a result of physical, and daily activities and the increase it plays on DJD within this region. With most of the male sample collected being that of black males the chances that they would be involved in more laborious activities is extremely high given their context seen above– which will be highlighted further on in this discussion. As is known from the sample that as selected, the black males present a

substantial number of the males which could be reason for the skewing of results and justification for the above.

Battié *et al.* (2004), combined with anatomical functions from Waxenbaum *et al.* (2023), identify this impact on lumbar vertebral joints as consistent and frequent physical loading from an upright posture does play a role. However, authors warn that there are other substantial factors such as hereditary, BMI and disc herniation from general ageing which could play a more significant role in disc degeneration (Battié *et al.*, 2004; Hangai *et al.*, 2008).

6.2.2. Population Affinity Differences

While there are few differences concerning different sexes and DJD, in this research, the trends seen between different population affinities suggest some interesting findings and support some of what has already been discussed. For this section it is crucial that the mean ages were considered in terms of the division of cohorts presented, with the black population group at 59 years of age and the white population group at 71 years of age this could skew how DJD is expressed between these two groups. Considering this the overall trend is still followed here in both the black and white cohorts with the shoulder (black = 2,15; white = 2,38) and hip (black = 1,93; white = 2,29) being the highest mean severity scores.

The work Jurmain (1980) published studied at DJD patterns from both prehistoric and modern populations. Their study showed that between these different population groups, the pattern of shoulder and hip joint involvement was the most affected. While work published by Johnson & Hunter (2014), describes that all joints react differently to the ageing process and that this is not entirely due to a predisposed individual alone. The results here argue that to an extent all joints will inherently act differently from a glance; however, by taking a closer look ball-and-socket joints are the most likely to be joints to be easily impacted by DJD and because of this will generally present with the highest severity across the body. The data represented here suggests that this could be a predictable pattern across skeletal observations of DJD, no matter the age of the individual or cohort. Future studies are needed to investigate the impact that DJD and wear-and-tear have on specific joint types.

Assessing at the population trends it is clear that black individuals had significantly higher mean severity DJD scores for the elbow ($p = 0,01$) and ankle ($p = 0,04$), as opposed to the white cohort. Not only does this further substantiate the claim above that these joints are influenced by physical activity (as seen with the higher scores in the black population), but it also indicates that the ankle may be more susceptible over the knee. Herrera-Pérez *et al.* (2021) also support this notion that the ankle joint is one of the greatest joints influenced by mechanical and physical factors. This specific hinge joint can withstand supporting immense loads of body weight when conducting physically intensive activities (Brocket & Chapman, 2016).

Lastly, the finger joint is worth mentioning, with both black and white cohorts indicating very similar mean severity scores of 1,90 and 1,94, respectively. What is of interest here is that very few studies have been conducted on the aetiology of the thumb metacarpophalangeal joint, and where this is done the authors propose that the DJD seen is due to high physical labour occupations (Feldon & Belsky, 1987; Shin & Osterman, 2008). Anatomically, the type of joint presented here would be identified as a condylar joint and therefore structurally capable of supporting large amounts of repetitive movement and therefore subject to activity-related patterns for DJD formation (Gupton *et al.*, 2023). With both black and white cohorts showing similar results for DJD severity across age and labour patterns, further studies should be implemented to better understand the high prevalence and cause within these joints.

6.2.3. Intersection Between Population Affinity and Sex Differences

By extending the trends seen above into population affinity and sex differences additional patterns of DJD can be derived and understood. The results continue the trend seen with the shoulder and then the hip being the two most impacted joints of DJD severity across all the cohorts (black and white, males and females) for this section, despite the varied groups' mean ages.

The results above highlight that black males and females showed very little difference in DJD severity scores with almost all showing no statistically significant change between them. One of the reasons that could potentially have led to this trend is the history of black individuals living in South Africa, especially since, but not exclusively, the early 1900s. This period

especially saw the increase of industrialisation in South Africa, and with that, high demand for a physical labour force in sectors such as mining, agriculture, infrastructure, and domestic work (Lalthapersad, 2003; Van der Merwe *et al.*, 2010; Steyn *et al.*, 2021). Given the unequal rights of black males and females, following the implementation of segregation and apartheid by the minority ruling parties, these people were predominantly forced into physical labour positions (Crankshaw, 2002). With black males being involved in mining, construction and agricultural activities and black females taking up the physically demanding domestic and manufacturing jobs (Lalthapersad, 2003). As DJD is known to be dependent on physical activity and wear-and-tear, these individuals may have been more prone to developing DJD (Jurmain, 1991; Lalthapersad, 2003; Watkins, 2012; Steyn *et al.*, 2021).

The results in this study mirror what has been stated above. With the understanding that the elbow and ankle are two of the joints that are most predominantly affected by physical activities - and in this sample the black individuals often filled this role. The results showed a marked increase in mean severity scores with black males (elbow = 1,94; ankle = 1,44) and black females (elbow = 2,04; ankle = 1,53) compared to white females (elbow = 1,52; ankle = 1,04). The white males were excluded from this comparison as the sample size collected from them was too small and not a clear representation of this population affinity. With the drastic age differences between white (mean = 75 years) and black (mean = 60 years) females, the assumption would have been that all joints may have skewed results towards the white females. However, the results indicate the elbow ($p = 0,002$) and ankle ($p = 0,004$) were still statistically significantly higher in the black females, indicating that physical activity may potentially be impacting these groups of individuals more so than age.

Specific attention should be given to the statistically significant differences in the TMJ mean scores between males and females ($p = 0,006$). When the TMJ mean severity scores are compared between black females (1,13) and white females (1,59) there seems to be no statistically significant differences ($p = 0,072$). While not statistically significant, this result does highlight that other forces are acting on the TMJ joint, apart from age and physical activities. The correlation of age and severity score clarifies that age is not an influential factor in the white population cohort with no correlation being established (Fig. 30).

With the TMJ mean severity score being so high for white females (1,59) against all other cohorts (black male = 0,80; black female = 1,13) this required further investigation. According to Tallents *et al.* (2002), they indicated that in cases where teeth were missing posteriorly or had been replaced with dentures, there was a significant correlation with an increase in TMJ DJD. This is important to note in white females as during the 1900s in South Africa, it was fashionable for individuals to wear full dentures – requiring the removal of all teeth (De Vries, 2013). Those who had access to dental care at the time, primarily white individuals, would have received this type of body modification and therefore an increased risk of TMJ DJD (Du Plessis *et al.*, 1988).

Lastly, regarding the axial skeleton with reference to the cervical and thoracic vertebrae, there is a marked increase in DJD in the white females (cervical = 1,63; thoracic = 1,48) in relation to the black females (cervical = 0,91; thoracic = 0,60), with the former presenting with the highest mean severity scores across all of the cohorts. These differences were statistically significant for white females over the black female cohort for both the cervical ($p = 0,009$) and thoracic ($p = 0,001$) vertebral joints.

In a paper published by Taitz (1999) on the cervical vertebra, they also reported that DJD had a greater prevalence in white individuals, stating that this was likely due to genetic differences in bone mineral density seen between different population groups, especially as individuals age and factors such as osteopenia and osteoporosis come into effect (Pollitzer & Anderson, 1989; Wright *et al.*, 1995). The thoracic vertebra also indicated a significant increase for white females against the black female subgroup which could be attributed to genetic but also potentially socio-economic differences as this relates to differences in diets. Holgate's (2020) thesis on DISH in the South African population proposes that there is a marked increase of DISH in thoracic vertebrae amongst white population groups – which could indicate why for this study a high mean severity score for the white males (2,29) were observed, even though the sample size is relatively small. Although it is still difficult to ascertain a direct aetiology for DISH, studies are emerging around metabolic activities as an influencing factor. According to Mader *et al.* (2013), DISH has been seen to be correlated with factors such as hypertension, obesity, glucose intolerance and high BMI. Archaeological studies also shed light on possible reasons behind DISH as being influenced more by protein and high calorie foods which were typically consumed by individuals of higher socio-

economic status (Jankauskas, 2003; Verlaan *et al.*, 2007; Holgate & Steyn, 2016). With both white males and females potentially consuming these types of food during the sample time period, this may be one explanation to the data found in this study.

6.2.4. Age

This section offers a summary of all the joints that have been discussed thus far and their relationship or non-relationship to age. As age increases, so do the mean severity scores for the following joints: TMJ, shoulder, wrist, finger, hip, knee, and toe joints. It is important to note that age is not the only defining factor in DJD progression, there will always be additional factors that have not been accounted for in this research specifically. Additionally, where there are unstratified ages for each cohort this provides a complex and unclear understanding of how age can be interpreted equally among each group and each joint. Future research could try and aim to provide information on how these different sex and population groups vary with age and DJD.

The results indicated that although DJD is not necessarily affected by age, there tends to be a positive correlation across most joints (seen in Appendix A). Work associated heavily with Jurmain (1977; 1980) postulates that there is a correlation between age and DJD, supporting what is seen in this study. The knee joint (Fig. 44) does have the weakest correlation with age for this section and this may be due to additional influences such as physical activity (Coggon *et al.*, 2001) and obesity (Coggon *et al.*, 2001).

Anatomically the inability to sustain joint homeostasis and the sheer nature of a degenerative disease dictates that with time the joint will slowly worsen. While aging is occurring here, there is also senescent factors that should be considered as well. A theory promoted by Howell (1976) on biological uniformitarianism states that while all organisms age, the rate of aging will not be constant. This could explain the differences seen between different joints and differences in their respective correlation rates.

The elbow and ankle failed to follow this same trend with the younger age cohort (elbow = 1,96; ankle = 1,54) groups (35-74) having higher severity mean scores than that of the older cohorts (75-94) (elbow = 1,71; ankle = 1,23). This is supported by the correlation graphs of the elbow (Fig. 33) and ankle (Fig. 35) indicating a negative correlation between age and

DJD in the white population. The results for the black population cohort for the elbow (Fig. 34) show that there is no correlation, whereas the ankle (Fig. 36) is inconclusive due to the skewing of scores in the centre of the graph. Jurmain (1980) concludes that DJD in peripheral joints such as the elbow and knee (ankle in this study) are more likely to be influenced by mechanical and physical activity-related factors, whereas joints such as the shoulder and hip are more closely related to changes in age, and therefore we can expect to see these disparities in the result when correlated to age.

The cervical, thoracic, and lumbar vertebral joints; however, indicated a progression between mean severity score and age. With all three of these areas increasing along each age cohort, it highlights the likelihood that as age increases, more degenerative changes will be seen. Allowing for degenerative joint disease in the axial skeleton to be linked to age-related changes and has been used in several studies to estimate age (Snodgrass, 2004; Watanabe & Terazawa, 2006; Praneatpolgrang *et al.*, 2019). Age estimation methods need to consider the role of physical-related activities (Battié *et al.*, 2004) across the spine and how this may impact the correctly estimated ages across these different sample groups. An example of this is found across the lumbar vertebral joints between the 55-74 and 75-94 age groups. The limited difference (0,01) shows that there such slight changes in mean severity scores between these two age groups (1,99) and (2,00), respectively.

6.3. *Activities of Daily Living*

When observing the impact of multiple affected joints and joint regions (in the TMJ, upper or lower peripheral or axial joints) it understandably would lead to a greater level of impairment (Gullo *et al.*, 2020). These affected joints would ultimately limit the amount of functionality the impaired individual has. This restriction on functioning is what is referred to as a limitation when attempting to complete an ADL. Each ADL can produce different degrees of limitation depending greatly on the social context of the particular individual (Gullo *et al.*, 2020).

The purpose of this section is to engage the reader with a different way of conducting research. There is no empirical way to definitively state that the information proposed here is precisely how these individuals were impacted by this disorder. What it does offer is an opportunity to engage with information and provide insight into what these individuals' lives

may have looked like based on the inferential data collected above and what is currently known about DJD as a whole. Caution should be taken here when applying this directly to other populations without the proper insight and understanding into what this study offers.

Assessing at the overall impact of ADLs throughout the study sample, it is clear that there are some general limitations which individuals may have experienced. The results indicate that activities such as transferring, walking, and eating may have been especially impacted with over 50% of the sample possibly having experienced severe pain and mobility reduction when attempting transferring and walking, and over 40% of individuals experiencing the same when attempting the eating ADL. What this means is that in a population where individuals have acquired DJD, nearly half of them could have experienced severe symptoms. With this information on the limitations that the overall population faces and given the state of the current public healthcare infrastructure, the country may likely face challenges in the future years with the influx of DJD and elderly individuals occupying these spaces (Kautzky & Tollman, 2008). A South African study conducted by Harling *et al.* (2020) indicated that middle-aged to older individuals in rural settings had the most problems with transferring and walking, similar to what was found in this study. This highlights the need for these two ADLs to be studied further, and to assist individuals in rural settings to accommodate for this limitation.

It has been well established in the literature that females in South Africa generally suffer from limitations in functioning and completing ADLs more often than males (Crimmins *et al.*, 2010; Gómez-Olivé *et al.*, 2010; Phaswana-Mafuya *et al.*, 2013; Pengpid & Peltzer, 2021). In the study conducted here, the highest mean severity scores were seen for females, with transferring (1,54), walking (1,47), eating (1,43), talking (0,6), object manipulation (0,99) and head rotation (0,6) ADLs. This trend towards females being more negatively impacted in most ADLs highlights the need to focus on DJD prevention and healthcare for these individuals. With many elderly females bearing the brunt of caregiving activities in multi-generational circumstances, their limitation in functioning is a huge problem that should be taken note of (Schats *et al.*, 2018). As seen by the mean ages in this study, females showed a tendency to outlive their male counterparts by a considerable amount. What this leads to is a division of resources within these family communities, where females who are in

their older ages would become more reliant on those around them for support (Schats *et al.*, 2018).

When turning the focus to population affinity it appears as though the white sample was more likely at risk of developing significant restrictions in ADLs, with almost all ADLs (transferring, 1,56; eating, 1,44; talking, 0,76; object manipulation, 0,97; walking, 1,59; head rotation, 0,71 and twisting, 0,85) scoring a higher mean severity score compared to the black population cohort. This was expected as there was a substantial difference in the mean ages between black and white sample groups (black = 58,9; white = 71,15), with the latter being substantially older. As is known, DJD is correlated with age with the older individuals expressing greater and more severe impaired functioning (Dunlop *et al.*, 1997; Sharma *et al.*, 2001; Covinsky, 2006; Covinsky *et al.*, 2008). However, despite the white population scoring higher than the black individuals, all of the ADLs were not statistically significant between the two groups. Indicating that both of these cohorts were similar enough that the null hypothesis was not rejected, highlighting that the younger black population group still showed very similar difficulties in ADL functionality. What this signifies is that although the white individuals are substantially older than that of the black cohort, the latter individuals still face the exact same level of disability.

There is an overlooked problem with the deduction above within South Africa. It is the age at which individuals can access the means-tested non-contributory government pension in South Africa that is not in line with the ages of the individuals who are suffering from this disability. According to Schatz *et al.* (2012), the ages at which individuals are available to claim from these pensions are females over 60 and males over 65. The data collected here indicates the higher need for individuals who were involved with greater physical activity, may need a lower age group for this type of pension to have an impact on the quality of life for them. While the sample was collected across the 1900s, there has been little change in the labour-intensive climate for these individuals nor has the pension been adjusted to accommodate their needs in terms of their inability to contribute to the working economy.

In cases where the intersection between population and sex is observed, there is a higher limitation for white females overall to complete most ADLs (eating, 1,44; talking, 0,78; object manipulation, 1,04; walking, 1,52; head rotation, 0,85; twisting, 0,74 and bending,

0,85). What is vital to highlight is that black females have a higher inability to complete the transferring ADLs. These older individuals are generally found in rural locations and are needed to fulfil the caregiving role of future generations, this increase in disability may be a significant concern. Black males had the highest impact on the functionality of bending ADLs. Some of these individuals may still working in high physical laborious activities (mining, agriculture, manufacturing) and therefore a lot of suffering is still likely to occur thus having a substantial impact on their quality of life (Harling *et al.*, 2020). With these individuals living in rural, multigenerational populations it not only impacts them but the family nucleus around them (Schats *et al.*, 2018).

6.4. Socio-economic Status

South Africa is a complex melting pot of past circumstances, complex cultures and overlooked minority groups. Situations of the past have very much been echoed in present day contexts with little change to the climate the population faces (Omotoso *et al.*, 2018), allowing for broad comparisons to be made between levels of socio-economic status and those who are compromised by disability. Aspects such as poverty, livelihood, access to transport, healthcare and financial care are all influenced by socio-economic status and the intersection these aspects will have on disabled individuals and will be looked at in the following section (Ataguba *et al.*, 2011; Young, 2016; Maphumulo & Bhengu, 2019).

Social implications should be strictly considered for this research project, as it has been stated that those who are from socioeconomically disadvantaged positions will already be prone to having poor health statuses and psychological distress (Gordon *et al.*, 2020). This is often seen where disabled individuals are typically marginalised, poorer and older - which all feed into the increasing risk factors for substandard health (Kuperi & Hanass-Hancock, 2020). Specifically, a distinct correlation between barriers to healthcare access and age plays a huge role, with older individuals not having sufficient funds or transportation to seek assistance (Henning-Smith *et al.*, 2016; Vergunst *et al.*, 2017). While old age will naturally play into how these individuals receive care, how age is considered between different SES groups needs to be better understood.

An example of this is seen in the results for this section. Lower SES individuals had higher mean severity scores for the elbow, 1,98; wrist, 1,61; knee, 1,78; ankle, 1,46 and lumbar

vertebra, 1,74. However, when age was controlled for (highlighting the difference in joint dysfunction at an equal age rate between SES groups) these same joints, as well as the shoulder and finger joints were higher in the lower SES individuals. The upper peripheral skeleton was greatly influenced, as all major joints in this region showed higher severity than the higher SES at the same age. Again this would be expected as these lower SES individuals would be involved in greater physical activity and prone to higher levels of wear and tear. This information provides great insight into future prevention methods as well as how best to assist the individuals in the most need.

The above individuals have been impaired severely at a younger age, which according to Harling and colleagues (2020) places these individuals at a greater risk of impairment. In their study, they found that individuals below the age of sixty, living in low-income areas, face greater challenges of unmet needs. Given their findings and the data collected here, this could be because there are no other individuals (e.g., their parents) who can take care of them. This may then force a negative feedback loop where their younger family members will have to assist these individuals, limiting the number of resources that can be used for the remainder of the family unit. A study conducted by Schatz *et al.* (2018) showed this when they indicated that most households in rural areas when assisting the elderly follow a complex-linked arrangements approach. Further promoting this theory that these younger, disabled individuals have to rely on other familial members, potentially because their own cannot support them.

Additionally, a yearlong study in 2008 in South Africa showed that over 40% of black, low-income individuals, reported not seeking medical care – with it being highly unlikely that these numbers have substantially changed since (Kon & Lackan, 2008). Additional barriers that these individuals with lower SES may face include vast distances with high associated costs, and payment for care that may often be self-funded, and disempowered patients (Harris *et al.*, 2011).

What the study conducted here ultimately shows is that these younger aged individuals, living in lower SES conditions, will face greater substantial challenges with close to or over 50% of individuals not being able to complete ADLs such as transferring (65%), eating (48%) and walking (60%) compared to their higher SES counterparts. With limitations in

medical care, financial care and family caregiving these individuals may often find themselves in extremely difficult situations.

A few case studies indicated below, discuss the limitation of living in lower SES areas concerning everyday functioning and care. As previously mentioned, limitations to the transferring ADL may limit the individual's ability to caretake (Schats *et al.*, 2018), and they may also face limitations in the ability to carry water to their home for use and sanitation (Wrisdale *et al.*, 2017), possible transportation and commuting restraints using poor public transport (Chakwizira *et al.*, 2021), as well as food insecurity and diet (Saha *et al.*, 2021). These all serve as additional challenges to younger individuals who are in a lower SES, by considering these is to understand the implications this may have on a disabled individual.

7. LIMITATIONS AND FUTURE DIRECTIONS

Most of the limitations that pertain to this research surround the sample that was used. Naturally, any sample that is selected would be skewed to the environment around it and the individuals that are within. A key example of this is the underrepresentation of white male individuals throughout the sample. This is a limitation brought on by the nature of the collection used, but also to some extent reflect the DJD trends seen within collections as indicated by the sampling procedure set out in this study. Future research could benefit from applying this methodology to a variety of different collections across Southern Africa and other countries of low socio-economic status.

The Raymond A. Dart Collection provided challenges when trying to classify the joints into specific scoring criteria. With this collection spanning over a century, it has seen various methodological changes in terms of maceration processes. When observing older individuals added to the collection these still had some joints still had large amounts of the cartilage covering the surfaces, due to previous cleaning methods. Future research needs to consider the limitation of bone cleanliness and adjust the methodology if necessary.

While secular changes in South Africa with regards to SES and the types of individuals living in specific conditions has not changed substantially from the date of the individuals death until current day, there may still be some changes that have occurred (Omotoso *et al.*, 2018). While this research has attempted to be broad in its findings and reporting on these impairments through an all-encompassing lens, there needs to be some space allowed for the fact that things potentially have changed and will change further.

Another limitation of this project was the lack of completeness of the demographic information obtained from these individuals. This was due to the database not being compiled of remains from one set source, leading to a biological profile being established using forensic anthropological methods. This information may influence the accuracy of the collection. While sex has been said to be easily determined, other forms of information such as population affinity and age have been said to be more difficult in their estimation (Dayal, 2009). It is also vital to note that senescent changes on osseous material are much more

limiting, compared to those on soft tissue limiting the extent of OA visibility (Tilley & Schrenk, 2017).

In cases of unclaimed individuals, these were often from migrant backgrounds and often had limited records with them. In lieu of this, the researcher had to use other methods for gathering information. Linear enamel hypoplasia and cribra orbitalia were used in determining SES to an extent. However, this can be seen as an unreliable process as these alterations to bone mainly occurred during childhood and thus did not necessarily indicate the socio-economic status of the individual throughout their life. Future research could start by determining if SES plays a role in the types of DJD and ADL impairment seen.

The above could be done by including more clinically aligned studies of the different types of symptoms seen in life and then comparing that to the skeletal material and classification system used in this study. This could be created slowly and throughout various communities, with the use of a sound database, this can be used and substantiated back to other studies conducted when only skeletal material remains. This was a substantial problem in this study and the inability to have a valid system for how the individual lived their lives is something that can be expanded on hugely in all aspects of bone diseases.

Lastly, there is a consideration to include other or all joints found within the skeleton. This research could only observe a limited number of joints and report on them. With particular reference to the articular facets found on vertebral joints, these have been known to suffer physically from DJD and could be another valuable joint to gather substantial information (Gellhorn *et al.*, 2012). Another reason for having two distinct scoring criteria for the vertebral body vs articular facets is to assist in scoring DJD cases where the neural arch is damaged and either section can still potentially be scored if the other is absent. Exploration into skeletal categorisation of these joints as well as clinical manifestations could be hugely beneficial in aspects of future research.

8. CONCLUSION

Degenerative joint disease and its implications have been shown throughout this research to be extremely complex in its interpretation – especially from skeletal remains. This study aimed to create a novel method for describing and defining DJD, the implications of this on activities of daily living and the contextual interplay between these two in a Southern African context. The following conclusions have been drawn from this research:

- This study developed a novel approach to score the progression of DJD on various joints in the skeletal system and then convert these scores to determine the level of impairment through the level of ADLs that could be completed. Given the results from the inter- and intra-repeatability studies, this novel method was shown to be reliable and accurate and can be re-used by individuals who are well-versed in the method.
- Overall DJD was more often and at higher severity levels observed in the shoulder and hip joints (or ball-and-socket joints) across the entire sample, indicating that these joints are likely the most susceptible to the degeneration brought on by joint disease.
- Females are most likely to be affected by DJD, with some of the probable causes being menopause in females.
- White population cohorts are most likely to be affected by DJD, with some of the probable causes the high age of the white population cohort.
- DJD in hinge joints, such as the elbow and ankles, did not show a correlation with age progression and therefore are more likely caused by physical activity and mechanical loading. These factors were mostly seen as the male, black population affinity, black males and black females all presented with some of the highest scores in their respective comparison groups.
- The white female individuals presented with statistically significantly higher frequencies and severity when it came to TMJ DJD. This has been considered to be due to the large number of females having dentures early on in life during this time and the secondary effects caused by attrition and biomechanical changes in the jaw.
- Age correlations indicated a positive relationship for all of the joints in relation to DJD severity, this however excluded the TMJ, elbow and ankle further substantiating

the that white females and black males are more prone to these types or impairments, respectively.

- The walking and transferring ADLs were the most severely impacted in the overall sample, with 50% of the sample experiencing severe symptoms when completing these activities.
- Higher limitations towards ADLs were faced by the females, white population affinity and the white female cohorts which may highlight the need for resources to assist these individuals.
- With black males representing the highest influence by the loss of the bending ADL, these individuals are forced to keep working physically laborious jobs without a government pension as they fall outside of the age limit.
- With lower SES suggesting a greater ADL impairment, these individuals require more resources. This may suggest these individuals face more challenges within the healthcare system and could require amendment.
- The lower SES may have faced more contextual challenges (pension and healthcare accessibility challenges) when attempting to complete some of the ADLs further impeding mobility issues.

Throughout this study the researcher has been very wary that this is not a study where the information can be cross-referenced, the researcher understand this and instead urges fellow academics in this field to investigate different ways of observing data and conducting studies. To find research gaps that could provide vital insight into individuals' lives where their stories have been untold. However, caution should always be taken when attempting to apply these methods as a one-size-fits-all approach without having a proper context first. In future research, it should be the duty of the researcher to implore their understanding and experience relating to the functionality of the joint and apply their judgements, within reason.

9. REFERENCES

- Abbas, J., Hamoud, K., May, H., Hay, O., Medlej, B., Masharawi, Y., Peled, N. and HersHKovitz, I. (2010). Degenerative lumbar spinal stenosis and lumbar spine configuration. *European Spine Journal*, 19(11), p. 1865-1873.
- Adams, B.D., Grosland, N.M., Murphy, D.M. and McCullough, M. (2003). Impact of impaired wrist motion on hand and upper-extremity performance. *The Journal of Hand Surgery*, 28(6), p. 898-903.
- Adams, M.A. and Roughley, P.J. (2006). What is intervertebral disc degeneration, and what causes it? *Spine*, 31(18), p. 2151-2161.
- Alakailly, X., Schwartz, D., Alwanni, N., Demko, C., Altay, M.A., Kilinc, Baur, D.A. and QueresHy, F. (2017). Patient-centered quality of life measures after alloplastic temporomandibular joint replacement surgery. *International Journal of Oral and Maxillofacial Surgery*, 46(2), p. 204-207.
- Allegrante, J.P. and Marks, R. (2003). Self-efficacy in management of osteoarthritis. *Rheumatic Disease Clinics*, 29(4), p. 747-768.
- Altman, R.D., Hochberg, M., Murphy Jr, W.A., Wolfe, F. and Lequesne, M. (1995). Atlas of individual radiographic features in osteoarthritis. *Osteoarthritis and Cartilage*, 3, p. 3-70.
- Amoroso, A., Garcia, S.J. and Cardoso, H.F. (2014). Age at Death and Linear Enamel Hypoplasias: Testing the Effects of Childhood Stress and Adult Socioeconomic Circumstances in Premature Mortality. *American Journal of Human Biology*, 26(4), p. 461-468.
- Anastasiou, D. and Kauffman, J.M. (2013). The Social Model of Disability: Dichotomy Between Impairment and Disability. *The Journal of Medicine and Philosophy*, 38(4), p. 441-459.
- Anderson, J.E. (1964). The people of Fairty: an osteological analysis of an Iroquois ossuary. *National Museum of Canada Bulletin*, 193, p. 28-129.
- Areheart, B.A. (2008). When Disability Isn't Just Right: The Entrenchment of the Medical Model of Disability and the Goldilocks Dilemma. *Indiana Law Journal*, 83, p. 181-232.
- Armelagos, G.J. (1968). Paleopathology of three archeological populations from Sudanese

- Nubia. *University of Colorado at Boulder*.
- Ataguba, J.E., Akazili, J. and McIntyre, D. (2011). Socioeconomic-related health inequality in South Africa: evidence from General Household Surveys. *International Journal for Equity in Health*, 10, p. 1-10.
- Atlas, S.J. and Delitto, A. (2006). Spinal stenosis: surgical versus nonsurgical treatment. *Clinical Orthopaedics and Related Research*, 443, p. 198-207.
- Aufderheide AC, Rodríguez-Martín C. (1998). *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge: Cambridge University Press.
- Battié, M.C., Videman, T. and Parent, E. (2004). Lumbar disc degeneration: epidemiology and genetic influences. *Spine*, 29(23), p. 2679-2690.
- Beaudry, J.S. (2016). Beyond (models of) disability?. In *The Journal of Medicine and Philosophy*, 41(2), p. 210-228.
- Benatar, S. (2013). The challenges of health disparities in South Africa. *South African Medical Journal*, 103(3), p. 154-155.
- Benjamin, M. and McGonagle, D. (2013). Normal functional anatomy of joints. *Oxford Textbook of Rheumatology*, p. 345.
- Berghs, M. (2017). Practices and discourses of ubuntu: Implications for an African model of disability?. *African Journal of Disability*, 6(1), p. 1-8.
- Bidmos, M.A. (2005). On the non-equivalence of documented cadaver lengths to living stature estimates based on Fully's method on bones in the Raymond A. Dart Collection. *Journal of Forensic Science*, 50(3), p. 1-6.
- Bijlsma, J.W., Berenbaum, F. and Lefeber, F.P. (2011). Osteoarthritis: an update with relevance for clinical practice. *The Lancet*, 377(9783), p. 2115-2126.
- Bobes Álvarez, C., Issa-Khozouz Santamaria, P., Fernández-Matías, R., Pecos-Martín, D., Achalandabaso-Ochoa, A., Fernández-Carnero, S., Martínez-Amat, A. and Gallego Izquierdo, T. (2020). Comparison of blood flow restriction training versus non-occlusive training in patients with anterior cruciate ligament reconstruction or knee osteoarthritis: a systematic review. *Journal of Clinical Medicine*, 10(1), p. 68.
- Botter, S.M., van Osch, G.J., Clockaerts, S., Waarsing, J.H., Weinans, H. and van Leeuwen, J.P. (2011). Osteoarthritis induction leads to early and temporal subchondral plate porosity in the tibial plateau of mice: an in vivo microfocal computed tomography study. *Arthritis and Rheumatism*, 63(9), p. 2690-2699.
- Brickley, M.B. (2018). Cribra orbitalia and porotic hyperostosis: A biological approach to

- diagnosis. *American Journal of Physical Anthropology*, 167(4), p. 896-902.
- Bridges, P.S. (1991). Degenerative joint disease in hunter–gatherers and agriculturalists from the southeastern United States. *American Journal of Physical Anthropology*, 85(4), p. 379-391.
- Brits, D.M., Billings, B.K., Kramer, B. and Hutchinson, E.F. (2020). The Altered Profile of a Donated Cadaver Population: Challenges for Teaching and Research? *European Journal of Anatomy*, p. 475-483.
- Brockett, C.L. and Chapman, G.J. (2016). Biomechanics of the ankle. *Orthopaedics and Trauma*, 30(3), p.232-238.
- Buchanan, W.W. and Kean, W.F. (2002). Osteoarthritis III: radiological and clinical definition. *Inflammopharmacology*, 10(1), p. 53-78.
- Buckwalter, J.A., Mankin, H.J. and Grodzinsky, A.J. (2005). Articular cartilage and osteoarthritis. *Instructional Course Lectures-American Academy of Orthopaedic Surgeons*, 54, p. 465.
- Buckwalter, J.A., Saltzman, C. and Brown, T. (2004). The impact of osteoarthritis: implications for research. *Clinical Orthopaedics and Related Research*, 427, p. 6-15.
- Buikstra, J.E., Ubelaker, D.H. and Haas, J. (1994). Standards for data collection from human skeletal remains: proceedings of a seminar at The Field Museum of Natural History. Arkansas Archeological Survey, Fayetteville, Ark.
- Burt, N.M., Semple, D., Waterhouse, K. and Lovell, N.C. (2013). Identification and interpretation of joint disease in paleopathology and forensic anthropology. Charles C Thomas Publisher.
- Byrnes, J.F. and Muller, J.L. (2017). Mind the Gap: Bridging Disability Studies and Bioarchaeology—An Introduction, In: Byrnes, J.F. and Muller, J.L. eds. *Bioarchaeology of Impairment and Disability*, Springer, Cham, p. 1–15.
- Cibulka, M.T., White, D.M., Woehrle, J., Harris-Hayes, M., Enseki, K., Fagerson, T.L., Slover, J. and Godges, J.J. (2009). Hip pain and mobility deficits—hip osteoarthritis: clinical practice guidelines linked to the international classification of functioning, disability, and health from the orthopaedic section of the American Physical Therapy Association. *Journal of Orthopaedic and Sports Physical Therapy*, 39(4), p. 1-25.
- Chakwizira, J., Bikam, P. and Adeboyejo, T.A. (2021). Access and constraints to commuting for persons with disabilities in Gauteng Province, South Africa. *Urban Inclusivity in Southern Africa*, p. 347-394.

- Cheung, E.V., Adams, R. and Morrey, B.F. (2008). Primary osteoarthritis of the elbow: current treatment options. *Journal of the American Academy of Orthopaedic Surgeons*, 16(2), p. 77-87.
- Chillemi, C. and Franceschini, V. (2013). Shoulder osteoarthritis, *Arthritis*, 2013, p. 1-7.
- Clynes, M.A., Jameson, K.A., Edwards, M.H., Cooper, C. and Dennison, E.M. (2019). Impact of osteoarthritis on activities of daily living: does joint site matter? *Aging Clinical and Experimental Research*, 31(8), p. 1049-1056.
- Coggon, D., Croft, P., Kellingray, S., Barrett, D., McLaren, M. and Cooper, C. (2000). Occupational physical activities and osteoarthritis of the knee. *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, 43(7), p.1443-1449.
- Coggon, D., Reading, I., Croft, P., McLaren, M., Barrett, D. and Cooper, C. (2001). Knee osteoarthritis and obesity. *International Journal of Obesity*, 25(5), p.622-627.
- Corti, M.C. and Rigon, C. (2003). Epidemiology of Osteoarthritis: Prevalence, Risk Factors and Functional Impact. *Aging Clinical and Experimental Research*, 15(5), p. 359-363.
- Coryell, P.R., Diekman, B.O. and Loeser, R.F. (2021). Mechanisms and therapeutic implications of cellular senescence in osteoarthritis. *Nature Reviews Rheumatology*, 17(1), p. 47-57.
- Covinsky, K. (2006). Aging, Arthritis, and Disability. *Arthritis Care and Research: Official Journal of the American College of Rheumatology*, 55(2), p. 175-176.
- Covinsky, K.E., Lindquist, K., Dunlop, D.D., Gill, T.M. and Yelin, E. (2008). Effect of Arthritis in Middle Age on Older-age Functioning. *Journal of the American Geriatrics Society*, 56(1), p. 23-28.
- Cox, M. and Mays, S. eds. (2000). Human osteology: in archaeology and forensic science. Cambridge University Press.
- Crankshaw, O. (2002). Race, class and the changing division of labour under apartheid. Routledge.
- Creamer, P., Lethbridge-Cejku, M. and Hochberg, M.C. (1999). Determinants of pain severity in knee osteoarthritis: effect of demographic and psychosocial variables using 3 pain measures. *The Journal of Rheumatology*, 26(8), p. 1785-1792.
- Creamer, P., Lethbridge-Cejku, M. and Hochberg, M.C. (2000). Factors Associated with Functional Impairment in Symptomatic Knee Osteoarthritis. *Rheumatology*, 39(5), p. 490-496.

- Crews, D.E. (2003). Human senescence: evolutionary and biocultural perspectives. Cambridge University Press.
- Crews, D.E. (2007). Senescence, Aging, and Disease. *Journal of Physiological Anthropology*, 26(3), p. 365-372.
- Crimmins, E.M., Kim, J.K. and Solé-Auró, A. (2011). Gender differences in health: results from SHARE, ELSA and HRS. *European journal of Public Health*, 21(1), p. 81-91.
- Cristofalo, V. J., Tresini, M., Francis, M. K., and Volker, C. (1999). Biological Theories of Senescence, In Bengtson, V.L. and Schaie, K.W. eds. Handbook of Theories of Aging, Springer Publishing Company, p. 98–112.
- Cross, M. (1999). Accessing the Inaccessible: Disability and Archaeology. *Archaeological Review from Cambridge*, 15(2), p. 7-30.
- Cucina, A. and İscan, M.Y. (1997). Assessment of Enamel Hypoplasia in a High Status Burial Site. *American Journal of Human Biology: The Official Journal of the Human Biology Association*, 9(2), p. 213-222.
- Davis, L. (2013). Introduction: Disability, Normality, and Power, In: Davis, L. ed. The Disability Studies Reader, New York: Routledge, p. 1-16.
- Dayal, M.R., Kegley, A.D., Štrkalj, G., Bidmos, M.A. and Kuykendall, K.L. (2009). The history and composition of the Raymond A. Dart Collection of human skeletons at the University of the Witwatersrand, Johannesburg, South Africa. *American Journal of Physical Anthropology*, 140(2), p. 324-335.
- De Vries, D. (2013). From Porcelain to Plastic: Politics and Business in a Relocated False Teeth Company, 1880s–1950s. *Enterprise and Society*, 14(1), p. 144-181.
- Dickel D.N. and Doran G.H. (1989) Severe neural tube defect syndrome from the Early Archaic of Florida. *American Journal of Physical Anthropology*, 80, p. 325–334.
- Dimitroulis, G. (2004). The interpositional dermis-fat graft in the management of temporomandibular joint ankylosis. *International Journal of Oral and Maxillofacial Surgery*, 33(8), p. 755-760.
- Doherty, M. and Preston, B. (1989). Primary osteoarthritis of the elbow. *Annals of the rheumatic diseases*, 48(9), p. 743-747.
- Doherty, M., Watt, I. and Dieppe, P. (1983). Influence of primary generalised osteoarthritis on development of secondary osteoarthritis. *The Lancet*, 322(8340), p. 8-11.
- Domett, K., Evans, C., Chang, N., Tayles, N. and Newton, J. (2017). Interpreting

- osteoarthritis in bioarchaeology: Highlighting the importance of a clinical approach through case studies from prehistoric Thailand. *Journal of Archaeological Science: Reports*, 11, p. 762-773.
- Drake, R.L., Vogl, A.W. and Mitchell, A.W. (2020). *Gray's Anatomy for Students* (4th ed.). Elsevier Health Sciences.
- Du Plessis, J.B., Rossouw, L.M., Smit, J. and Lichter, G., (1988). Prosthetic status and treatment needs of the adult population of South Africa. *National oral health survey: South Africa*, 89, p.93-01.
- Dunlop, D.D., Hughes, S.L. and Manheim, L.M. (1997). Disability in Activities of Daily Living: Patterns of Change and a Hierarchy of Disability. *American Journal of Public Health*, 87(3), p. 378-383.
- Edemekong, P.F., Bomgaars, D.L. and Levy, S.B. (2017). *Activities of daily living (ADLs)*. StatPearls Publishing.
- Edemekong, P.F., Bomgaars, D.L., Sukumaran, S. and Levy, S.B. (2021). *Activities of daily living*. StatPearls Publishing.
- Eisenstein, S. (1977). The morphometry and pathological anatomy of the lumbar spine in South African negroes and caucasoids with specific reference to spinal stenosis. *The Journal of Bone and Joint Surgery*, 59(2), p. 173-180.
- El-Najjar, M.Y., Desanti, M.V. and Ozebek, L. (1978). Prevalence and possible etiology of dental enamel hypoplasia. *American Journal of Physical Anthropology*, 48(2), p. 185-192.
- Emshoff, R. and Rudisch, A. (2003). Are internal derangement and osteoarthrosis linked to changes in clinical outcome measures of arthrocentesis of the temporomandibular joint?. *Journal of Oral and Maxillofacial Surgery*, 61(10), p. 1162-1167.
- Farr, J.N., Fraser, D.G., Wang, H., Jaehn, K., Ogrodnik, M.B., Weivoda, M.M., Drake, M.T., Tchkonja, T., LeBrasseur, N.K., Kirkland, J.L. and Bonewald, L.F. (2016). Identification of senescent cells in the bone microenvironment. *Journal of Bone and Mineral Research*, 31(11), p. 1920-1929.
- Farr, J.N. and Khosla, S. (2015). Skeletal changes through the lifespan—from growth to senescence. *Nature Reviews Endocrinology*, 11(9), p. 513-521.
- Fautrel, B., Hilliquin, P., Rozenberg, S., Allaert, F.A., Coste, P., Leclerc, A. and Rossignol, M. (2005). Impact of osteoarthritis: results of a nationwide survey of 10,000 patients consulting for OA. *Joint Bone Spine*, 72(3), p. 235-240.

- Feldon, P. and Belsky, M.R. (1987). Degenerative diseases of the metacarpophalangeal joints. *Hand Clinics*, 3(3), p. 429-445.
- Fernandes, C.L. (2004). Forensic ethnic identification of crania: the role of the maxillary sinus—a new approach. *The American Journal of Forensic Medicine and Pathology*, 25(4), p. 302-313.
- Ferrara, L.A. (2012). The biomechanics of cervical spondylosis. *Advances in Orthopedics*, 2012, p. 1-5
- Fransen, M., Bridgett, L., March, L., Hoy, D., Penserga, E. and Brooks, P. (2011). The epidemiology of osteoarthritis in Asia. *International Journal of Rheumatic Diseases*, 14(2), p. 113-121.
- Friedman, M. J., and McEwen, B. S. (2004). Posttraumatic Stress Disorder, Allostatic Load, and Medical Illness, In: Schnurr, P.P. and Green, B.L. eds. *Trauma and Health: Physical Health Consequences of Exposure to Extreme Stress*, American Psychological Association, p. 157–188.
- Fusco, M., Skaper, S.D., Coaccioli, S., Varrassi, G. and Paladini, A. (2017). Degenerative joint diseases and neuroinflammation. *Pain Practice*, 17(4), p. 522-532.
- Gellhorn, A.C., Katz, J.N. and Suri, P. (2013). Osteoarthritis of the spine: the facet Joints. *Nature Reviews Rheumatology*, 9(4), p. 216-224.
- Gelse, K., Söder, S., Eger, W., Diemtar, T. and Aigner, T. (2003). Osteophyte development—molecular characterization of differentiation stages. *Osteoarthritis and Cartilage*, 11(2), p. 141-148.
- Gignac, M.A., Cott, C. and Badley, E.M. (2000). Adaptation to chronic illness and disability and its relationship to perceptions of independence and dependence. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 55(6), p. P362 – P372.
- Goering, S. (2015). Rethinking disability: the social model of disability and chronic disease. *Current Reviews in Musculoskeletal Medicine*, 8, p. 134-138.
- Goldring, M.B. and Goldring, S.R. (2010). Articular cartilage and subchondral bone in the pathogenesis of osteoarthritis. *Annals of the New York Academy of Sciences*, 1192(1), p. 230-237.
- Goode, A.P., Carey, T.S. and Jordan, J.M. (2013). Low back pain and lumbar spine osteoarthritis: how are they related? *Current Rheumatology Reports*, 15(2), p. 1-8.
- Goodley, D. (2014). Disability studies: Theorising disablism and ableism. Oxford: Routledge.

- Goodman, A.H. and Rose, J.C. (1991). Dental Enamel Hypoplasias as Indicators of Nutritional Status. *Advances in Dental Anthropology*, 5, p. 225-240.
- Goodman, A.H. and Leatherman, T.L. (1998). Traversing the Chasm Between Biology, In: Goodman, A.H. and Leatherman, T.L. eds. Building a New Biocultural Synthesis: Political economic Perspectives on Human Biology. University of Michigan Press.
- Goodman, A. H., and Martin, D. L. (2002). Reconstructing Health Profiles from Skeletal Remains. In R. H. Steckel and J. C. Rose (Eds.), The back- bone of history: Health and nutrition in the Western Hemisphere. New York: Cambridge University Press.
- Gordon, M.S., Russell, B.S. and Finan, L.J. (2020). The influence of parental support and community belonging on socioeconomic status and adolescent substance use over time. *Substance Use and Misuse*, 55(1), p. 23-36.
- Gramstad, G.D. and Galatz, L.M. (2006). Management of elbow osteoarthritis. *Journal of Bone and Joint Surgery*, 88(2), p. 421-430.
- Gullo, T.R., Golightly, Y.M., Cleveland, R.J., Renner, J.B., Callahan, L.F., Jordan, J.M., Kraus, V.B. and Nelson, A.E. (2019). Defining multiple joint osteoarthritis, its frequency and impact in a community-based cohort. *In Seminars in Arthritis and Rheumatism*, 48(6), p. 950-957.
- Gupton, M., Munjal, A. and Terreberry, R.R. (2023). Anatomy, hinge joints. *StatPearls Publishing*.
- Haegele, J.A. and Hodge, S. (2016). Disability discourse: Overview and critiques of the medical and social models. *Quest*, 68(2), p. 193-206.
- Haeusler, M., Trinkaus, E., Fornai, C., Müller, J., Bonneau, N., Boeni, T. and Frater, N. (2019). Morphology, pathology, and the vertebral posture of the La Chapelle-aux-Saints Neandertal. *Proceedings of the National Academy of Sciences*, 116(11), p. 4923-4927.
- Hammell, K. (2004). Deviating from the norm: A sceptical interrogation of the classificatory practices of the ICF. *British Journal of Occupational Therapy*, 67(9), p. 408–411.
- Hangai, M., Kaneoka, K., Kuno, S., Hinotsu, S., Sakane, M., Mamizuka, N., Sakai, S. and Ochiai, N. (2008). Factors associated with lumbar intervertebral disc degeneration in the elderly. *The Spine Journal*, 8(5), p. 732-740.
- Hardcastle, S.A., Dieppe, P., Gregson, C.L., Arden, N.K., Spector, T.D., Hart, D.J., Edwards,

- M.H., Dennison, E.M., Cooper, C., Williams, M. and Davey Smith, G. (2014). Osteophytes, enthesophytes, and high bone mass: a bone-forming triad with potential relevance in osteoarthritis. *Arthritis and Rheumatology*, 66(9), p. 2429-2439.
- Harling, G., Payne, C.F., Davies, J.I., Gomez-Olive, F.X., Kahn, K., Manderson, L., Mateen, F.J., Tollman, S.M. and Witham, M.D. (2020). Impairment in activities of daily living, care receipt, and unmet needs in a middle-aged and older rural South African population: Findings from the HAALSI study. *Journal of Aging and Health*, 32(5-6), p. 296-307.
- Harris, B., Goudge, J., Ataguba, J.E., McIntyre, D., Nxumalo, N., Jikwana, S. and Chersich, M. (2011). Inequities in access to health care in South Africa. *Journal of Public Health Policy*, 32, p. 102-123.
- Hartigan, I. (2007). A comparative review of the Katz ADL and the Barthel Index in assessing the activities of daily living of older people. *International Journal of Older People Nursing*, 2(3), p. 204-212.
- Hawkey, D.E. (1998). Disability, compassion and the skeletal record: using musculoskeletal stress markers (MSM) to construct an osteobiography from early New Mexico. *International Journal of Osteoarchaeology*, 8(5), p. 326-340.
- Henning-Smith, C.E., Gonzales, G. and Shippee, T.P. (2016). Barriers to Timely Medical Care for Older Adults by Disability Status and Household Composition. *Journal of Disability Policy Studies*, 27(2), p. 116-127.
- Henson, K., Harding, T., Starcher, K., Smith, A. and Securro, D. (2020). Intraobserver and interobserver error in osteological analysis as an indicator for non-expert skeletal analysis. *Journal of Forensic Science and Criminology*, 8(1), p. 104.
- Herrera-Pérez, M., González-Martín, D., Vallejo-Márquez, M., Godoy-Santos, A.L., Valderrabano, V. and Tejero, S. (2021). Ankle osteoarthritis aetiology. *Journal of Clinical Medicine*, 10(19), p. 4489.
- Hillson, S. (2014). Tooth development in human evolution and bioarchaeology. Cambridge University Press.
- Holgate, R.L. and Steyn, M. (2016). Diffuse idiopathic skeletal hyperostosis: Diagnostic, clinical, and paleopathological considerations. *Clinical anatomy*, 29(7), p. 870-877.
- Holgate, R.L.V. (2020). A multidisciplinary approach to investigate the manifestations of Diffuse Idiopathic Skeletal Hyperostosis (DISH) in modern South African skeletal remains. *Doctoral dissertation, University of Pretoria*.

- Hou, X., Sun, C., Liu, X., Liu, Z., Qi, Q., Guo, Z., Li, W., Zeng, Y. and Chen, Z. (2016). Clinical features of thoracic spinal stenosis-associated myelopathy: a retrospective analysis of 427 cases. *Clinical Spine Surgery*, 29(2), p. 86-89.
- Howell, N. (1976). Towards an uniformitarian theory of human pleistodemography. In: Ward, R.H. and Weiss, L.M. (eds.). *The Demographic Evolution of Human Populations*. New York Academic Press, p. 25-40.
- Ibi, M. (2019). Inflammation and temporomandibular joint derangement. *Biological and Pharmaceutical Bulletin*, 42(4), p. 538-542.
- Iezzoni, L.I., Kurtz, S.G. and Rao, S.R. (2014). Trends in US adult chronic disability rates over time. *Disability and Health Journal*, 7(4), p. 402-412.
- Jagur, O., Kull, M., Leibur, E., Kallikorm, R. and Lember, M. (2012). The associations of TMJ pain and bone characteristics on the activities of daily living. *Open Journal of Stomatology*, 2, p. 237-243.
- Jankauskas, R. (2003). The incidence of diffuse idiopathic skeletal hyperostosis and social status correlations in Lithuanian skeletal materials. *International Journal of Osteoarchaeology*, 13(5), p. 289-293.
- Jespersen, L.N., Michelsen, S.I., Tjørnhøj-Thomsen, T., Svensson, M.K., Holstein, B.E. and Due, P. (2019). Living with a disability: a qualitative study of associations between social relations, social participation and quality of life. *Disability and Rehabilitation*, 41(11), p. 1275-1286.
- Johnson, V.L. and Hunter, D.J. (2014). The epidemiology of osteoarthritis. *Best Practice and Research Clinical Rheumatology*, 28(1), p. 5-15.
- Juneja, P., Munjal, A. and Hubbard, J.B. (2023). Anatomy, joints. *StatPearls Publishing*.
- Jurmain, R.D. (1977). Stress and the etiology of osteoarthritis. *American Journal of Physical Anthropology*, 46(2), p. 353-365.
- Jurmain, R.D. (1980). The pattern of involvement of appendicular degenerative joint disease. *American Journal of Physical Anthropology*, 53(1), p. 143-150.
- Jurmain, R.D. (1991). Degenerative changes in peripheral joints as indicators of mechanical stress: opportunities and limitations. *International Journal of Osteoarchaeology*, 1(3-4), p. 247-252.
- Jurmain, R.D. and Kilgore, L. (1995). Skeletal Evidence of Osteoarthritis: A Palaeopathological Perspective. *Annals of the Rheumatic Diseases*, 54(6), p. 443-450.
- Kadam, U.T. and Croft, P.R. (2007). Clinical comorbidity in osteoarthritis: associations with

- physical function in older patients in family practice. *The Journal of Rheumatology*, 34(9), p. 1899-1904.
- Kadam, U.T., Jordan, K. and Croft, P.R. (2004). Clinical comorbidity in patients with osteoarthritis: a case-control study of general practice consultants in England and Wales. *Annals of the Rheumatic Diseases*, 63(4), p. 408-414.
- Kalichman, L. and Hernández-Molina, G. (2010). Hand osteoarthritis: an epidemiological perspective. *In Seminars in Arthritis and Rheumatism*, 39(6), p. 465-476.
- Kang, B., Jung, G.H., Kholinne, E., Jeon, I.H. and Kwak, J.M. (2023). The elbow is the load-bearing joint during arm swing. *Clinics in Shoulder and Elbow*, 26(2), p.126.
- Karsdal, M.A., Bay-Jensen, A.C., Henriksen, K. and Christiansen, C. (2012). The pathogenesis of osteoarthritis involves bone, cartilage and synovial inflammation: may estrogen be a magic bullet? *Menopause international*, 18(4), p. 139-146.
- Katz, S., Downs, T.D., Cash, H.R. and Grotz, R.C. (1970). Progress in Development of the Index of ADL. *The Gerontologist*, 10, p. 20-30.
- Kautzky, K. and Tollman, S.M. (2008). A perspective on primary health care in South Africa: Primary health care: In context. *South African health Review*, 2008(1), p. 17-30.
- Kent, L. (2016). Health-related care for the Neanderthal Shanidar 1. *ANU Undergraduate Research Journal*, 8, p. 83-91.
- Kilgore, L. (1985). Degenerative Joint Disease In A Medieval Nubian Population (Sudan). University of Colorado at Boulder.
- Kim, D.K., Kim, M.J., Kim, Y.S., Oh, C.S. and Shin, D.H. (2012). Vertebral osteophyte of pre-modern Korean skeletons from Joseon tombs. *Anatomy and Cell Biology*, 45(4), p. 274-281.
- King, T., Hillson, S. and Humphrey, L.T. (2002). A detailed study of enamel hypoplasia in a post-medieval adolescent of known age and sex. *Archives of Oral Biology*, 47(1), p. 29-39.
- Kirkwood, T.B. (1996). Human Senescence. *Bioessays*, 18(12), p. 1009-1016.
- Kiss, C., Szilagyi, M., Paksy, A. and Poor, G. (2002). Risk factors for diffuse idiopathic skeletal hyperostosis: a case-control study. *Rheumatology*, 41(1), p. 27-30.
- Klaassen, Z., Tubbs, R.S., Apaydin, N., Hage, R., Jordan, R. and Loukas, M. (2011). Vertebral Spinal Osteophytes. *Anatomical Science International*, 86(1), p. 1-9.
- Klaus, H.D., Spencer Larsen, C. and Tam, M.E. (2009). Economic intensification and

- degenerative joint disease: life and labor on the postcontact north coast of Peru. *American Journal of Physical Anthropology*, 139(2), p. 204-221.
- Kloppenburger, M. and Kwok, W.Y. (2012). Hand osteoarthritis—a heterogeneous disorder. *Nature Reviews Rheumatology*, 8(1), p. 22-31.
- Kon, Z.R. and Lackan, N. (2008). Ethnic disparities in access to care in post-apartheid South Africa. *American Journal of Public Health*, 98(12), p. 2272-2277.
- Kozak, T.K., Adams, R.A. and Morrey, B.F. (1998). Total elbow arthroplasty in primary osteoarthritis of the elbow. *The Journal of Arthroplasty*, 13(7), p. 837-842.
- Kubiak, E.N., Moskovich, R., Errico, T.J. and Di Cesare, P.E. (2005). Orthopaedic management of ankylosing spondylitis. *Journal of the American Academy of Orthopaedic Surgeons*, 13(4), p. 267-278.
- Kumaresan, S., Yoganandan, N., Pintar, F.A., Maiman, D.J. and Goel, V.K. (2001). Contribution of disc degeneration to osteophyte formation in the cervical spine: a biomechanical investigation. *Journal of Orthopaedic Research*, 19(5), p. 977-984.
- Kuperi, H. and Hanass-Hancock, J. (2020). Framing the Debate on How to Achieve Equitable Health Care for Persons with Disabilities in South Africa. *South African Health Review*, 2020(1), p. 45-52.
- Kuperus, J.S., Hoesein, F.A.M., de Jong, P.A. and Verlaan, J.J., 2020. Diffuse idiopathic skeletal hyperostosis: Etiology and clinical relevance. *Best Practice and Research Clinical Rheumatology*, 34(3), p.101527.
- L'Abbé, E.N. and Steyn, M. (2007). Health status of the Venda, a post-antibiotic community in rural South Africa. *International Journal of Osteoarchaeology*, 17(5), p. 492-503.
- Lalthapersad, P. (2003). Historical analysis of African women workers in South Africa during the period 1900 to 2000. *South African Journal of Economic and Management Sciences*, 6(2), p. 262-273.
- Landsman, C., Meyer, A. and Steyn, M. (2022). A bioarchaeological analysis of skeletal remains from Van Zyl's farm, Clarens, Free State, South Africa. *Southern African Field Archaeology*, 17.
- Laplanche, B.L. and DePalma, M.J. (2012). Spine Osteoarthritis, *American Academy of Physical Medicine and Rehabilitation*, 4, p. 28-36.
- Larsen, C.S. (2015). *Bioarchaeology: Interpreting behavior from the human skeleton* (Vol. 69). Cambridge University Press.
- Larsen, C.S. (2002). Bioarchaeology: The Lives and Lifestyles of Past People. *Journal of*

- Archaeological Research*, 10(2), p. 119-166.
- Laulan, J., Marteau, E. and Bacle, G. (2015). Wrist osteoarthritis. *Orthopaedics and Traumatology: Surgery and Research*, 101(1), p. 1-9.
- Leonardi, M., Bickenbach, J., Ustun, T.B., Kostanjsek, N. and Chatterji, S. (2006). The Definition of Disability: What is in a Name?. *The Lancet*, 368(9543), p. 1219-1221.
- Lesciotto, K.M. and Doershuk, L.J. (2018). Accuracy and reliability of the Klales et al.(2012) morphoscopic pelvic sexing method. *Journal of Forensic Sciences*, 63(1), p. 214-220.
- Li, B., Marshall, D., Roe, M. and Aspden, R.M. (1999). The electron microscope appearance of the subchondral bone plate in the human femoral head in osteoarthritis and osteoporosis. *The Journal of Anatomy*, 195(1), p. 101-110.
- Li, G., Yin, J., Gao, J., Cheng, T.S., Pavlos, N.J., Zhang, C. and Zheng, M.H. (2013). Subchondral bone in osteoarthritis: insight into risk factors and microstructural changes. *Arthritis Research and Therapy*, 15, p. 1-12.
- Lieverse, A.R., Weber, A.W., Bazaliiskiy, V.I., Goriunova, O.I. and Savel'ev, N.A. (2007). Osteoarthritis in Siberia's Cis-Baikal: Skeletal indicators of hunter-gatherer adaptation and cultural change. *American Journal of Physical Anthropology*, 132(1), p. 1-16.
- Lim, Y.W., van Riet, R.P., Mittal, R. and Bain, G.I. (2008). Pattern of osteophyte distribution in primary osteoarthritis of the elbow. *Journal of Shoulder and Elbow Surgery*, 17(6), p. 963-966.
- Listi, G.A. and Manhein, M.H. (2012). The use of vertebral osteoarthritis and osteophytosis in age estimation. *Journal of Forensic Sciences*, 57(6), p. 1537-1540.
- Litwic, A., Edwards, M.H., Dennison, E.M. and Cooper, C. (2013). Epidemiology and burden of osteoarthritis. *British Medical Bulletin*, 105(1), p. 185-199.
- Llewellyn, A. and Hogan, K. (2000). The use and abuse of models of disability. *Disability and Society*, 15(1), p. 157-165.
- Llewellyn, A., Agu, L. and Mercer, D. (2008), *Sociology for social workers*, Polity, Cambridge, United Kingdom.
- Loeser, R.F., Goldring, S.R., Scanzello, C.R. and Goldring, M.B. (2012). Osteoarthritis: a disease of the joint as an organ. *Arthritis and Rheumatism*, 64(6), p. 1697.
- Lou, C., Xiang, G., Weng, Q., Chen, Z., Chen, D., Wang, Q., Zhang, D., Zhou, B., He, D. and Chen, H. (2016). Menopause is associated with articular cartilage degeneration: a clinical study of knee joint in 860 women. *Menopause*, 23(11), p. 1239-1246.
- Lovell, N.C. (2016). Tiptoeing through the rest of his life: A functional adaptation to a leg

- shortened by femoral neck fracture. *International Journal of Paleopathology*, 13, p. 91-95.
- Luna L.H., Aranda C.M., Bosio L.A., and Beron M.A. (2008) A case of multiple metastasis in Late Holocene hunter-gatherers from the Argentine Pampean region. *International Journal of Osteoarchaeology*, 18, p. 492–506.
- Maart, S. and Jelsma, J. (2014). Disability and access to health care—a community based descriptive study. *Disability and Rehabilitation*, 36(18), p. 1489-1493.
- Mader, R., Verlaan, J.J. and Buskila, D. (2013). Diffuse idiopathic skeletal hyperostosis: clinical features and pathogenic mechanisms. *Nature Reviews Rheumatology*, 9(12), p. 741-750.
- Mahoney, F.I. and Barthel, D. (1965). Functional evaluation: the Barthel index. *Maryland State Medical Journal*, 14(2), p. 61-65.
- Maloney, T.R., Dilkes-Hall, I.E., Vlok, M., Oktaviana, A.A., Setiawan, P., Priyatno, A.A.D., Ririmasse, M., Geria, I.M., Effendy, M.A., Istiawan, B. and Atmoko, F.T. (2022). Surgical amputation of a limb 31,000 years ago in Borneo. *Nature*, 609(7927), p. 547-551.
- Maly, M.R. and Krupa, T. (2007). Personal Experience of Living with Knee Osteoarthritis Among Older Adults. *Disability and Rehabilitation*, 29(18) p. 1423-1433.
- Mander, M., Ntuli, L., Diederichs, N. and Mavundla, K. (2007). Economics of the traditional medicine trade in South Africa care delivery. *South African Health Review*, 2007(1), p. 189-196.
- Manolagas, S.C. and Parfitt, A.M. (2010). What old means to bone. *Trends in Endocrinology and Metabolism*, 21(6), p. 369-374.
- Maphumulo, W.T. and Bhengu, B.R. (2019). Challenges of Quality Improvement in the Healthcare of South Africa Post-apartheid: A Critical Review. *Curationis*, 42(1), p. 1-9.
- Marie, P.J. (2014). Bone Cell Senescence: Mechanisms and Perspectives. *Journal of Bone and Mineral Research*, 29(6), p. 1311-1321.
- Marklein, K.E., Leahy, R.E. and Crews, D.E. (2016). In Sickness and in Death: Assessing Frailty in Human Skeletal Remains. *American Journal of Physical Anthropology*, 161(2), p. 208-225.
- Marks, D. (1997). Models of disability. *Disability and Rehabilitation*, 19(3), p. 85-91.
- Martin, J.A. and Buckwalter, J.A. (2002). Aging, articular cartilage chondrocyte senescence

- and osteoarthritis. *Biogerontology*, 3(5), p. 257-264.
- Mata, S., Fortin, P.R., Fitzcharles, M.A., Starr, M.R., Joseph, L., Watts, C.S., Gore, B., Rosenberg, E., Chhem, R.K. and Esdaile, J.M. (1997). A controlled study of diffuse idiopathic skeletal hyperostosis clinical features and functional status. *Medicine*, 76(2), p. 104-117.
- Mays, S., Turner-Walker, G. and Syversen, U. (2006). Osteoporosis in a Population from Medieval Norway. *American Journal of Physical Anthropology*, 131(3), p. 343-351.
- Mays, S.A. (1999). Osteoporosis in Earlier Human Populations. *Journal of Clinical Densitometry*, 2(1), p. 71-78.
- McCormack, B.M. and Weinstein, P.R. (1996). Cervical spondylosis. *Western Journal of Medicine*, 165(1-2), p. 43.
- McDonough, C.M. and Jette, A.M. (2010). The Contribution of Osteoarthritis to Functional Limitations and Disability. *Clinics in Geriatric Medicine*, 26(3), p. 387-399.
- McEwen, B.S. and Seeman, T. (1999). Protective and Damaging Effects of Mediators of Stress: Elaborating and Testing the Concepts of Allostasis and Allostatic Load. *Annals of the New York Academy of Sciences*, 896(1), p. 30-47.
- McHugh, M.L. (2012). Interrater reliability: the kappa statistic. *Biochemia Medica*, 22(3), p. 276-282.
- McMahon, B.T. and Shaw, L.R. (2005). Workplace discrimination and disability. *Journal of Vocational Rehabilitation*, 23(3), p. 137-143.
- Meade, M.A., Mahmoudi, E. and Lee, S.Y. (2015). The intersection of disability and healthcare disparities: a conceptual framework. *Disability and Rehabilitation*, 37(7), p. 632-641.
- Melancia, J.L., Francisco, A.F. and Antunes, J.L. (2014). Spinal stenosis. *Handbook of Clinical Neurology*, 119, p. 541-549.
- Miles, J.S. (1966). Diseases encountered at Mesa Verde, Colorado. II. Evidences of disease. *S. Jarcho*, p. 91-97.
- Millett, P.J., Gobezie, R. and Boykin, R.E. (2008). Shoulder osteoarthritis: diagnosis and management. *American Family Physician*, 78(5), p. 605-611.
- Mlinac, M.E. and Feng, M.C. (2016). Assessment of activities of daily living, self-care, and independence. *Archives of Clinical Neuropsychology*, 31(6), p. 506-516.
- Molnar, P., Ahlstrom, T.P. and Leden, I. (2011). Osteoarthritis and activity—an analysis of

- the relationship between eburnation, musculoskeletal stress markers (MSM) and age in two Neolithic hunter–gatherer populations from Gotland, Sweden. *International Journal of Osteoarchaeology*, 21(3), p. 283-291.
- Munteanu, S.E., Zammit, G.V. and Menz, H.B. (2012). Factors associated with foot pain severity and foot-related disability in individuals with first metatarsophalangeal joint OA. *Rheumatology*, 51(1), p. 176-183.
- Mutwali, R. and Ross, E. (2019). Disparities in Physical Access and Healthcare Utilization Among Adults with and without Disabilities in South Africa. *Disability and Health Journal*, 12(1), p. 35-42.
- Nathan, H. (1962). Osteophytes of the vertebral column: an anatomical study of their development according to age, race, and sex with considerations as to their etiology and significance. *The Journal of Bone and Joint Surgery*, 44(2), p. 243-268.
- Neogi, T. and Zhang, Y. (2013). Epidemiology of osteoarthritis. *Rheumatic Disease Clinics*, 39(1), p. 1-19.
- Nevitt, M.C. and Felson, D.T. (1996). Sex hormones and the risk of osteoarthritis in women: epidemiological evidence. *Annals of the Rheumatic Diseases*, 55(9), p. 673.
- Niosi, C.A. and Oxland, T.R. (2004). Degenerative mechanics of the lumbar spine. *The Spine Journal*, 4(6), p. 202-208.
- O'Dwyer, T., O'Shea, F. and Wilson, F. (2014). Exercise therapy for spondyloarthritis: a systematic review. *Rheumatology International*, 34, p. 887-902.
- Oliver, M. (1990). Disability definitions: the politics of meaning. In *The politics of Disablement*. Palgrave, London.
- Omotoso, K.O. and Koch, S.F. (2018). Assessing changes in social determinants of health inequalities in South Africa: A decomposition analysis. *International Journal for Equity in Health*, 17(1), p. 1-13.
- Ortner, D. J. (2003). *Identification of Pathological Conditions in Human Skeletal Remains*. London: London Academic Press.
- Oxenham, M.F., Tilley, L., Matsumura, H., Nguyen, L.C., Nguyen, K.T., Nguyen, K.D., Domett, K. and Huffer, D. (2009). Paralysis and severe disability requiring intensive care in Neolithic Asia. *Anthropological Science*, 117(2), p. 107-112.
- Özdemir, F., Birtane, M. and Kokino, S. (2001). The clinical efficacy of low-power laser therapy on pain and function in cervical osteoarthritis. *Clinical Rheumatology*, 20, p. 181-184.

- Paine, R.R., Vargiu, R., Signoretti, C. and Coppa, A. (2009). A health assessment for Imperial Roman burials recovered from the necropolis of San Donato and Bivio CH, Urbino, Italy. *Journal of Anthropological Sciences*, 87, p. 193-210.
- Payne, C.F., Gómez-Olivé, F.X., Kahn, K. and Berkman, L. (2017). Physical function in an aging population in rural South Africa: Findings from HAALSI and cross-national comparisons with HRS sister studies. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 72(4), p. 665-679.
- Pengpid, S. and Peltzer, K. (2021). Ethnic and Gender Disparities in Healthy Ageing among People 50 Years and Older in South Africa. *Geriatrics*, 6(3), p. 79.
- Penninx, B.W., Beekman, A.T., Ormel, J., Kriegsman, D.M., Boeke, A.J.P., Van Eijk, J.T.M. and Deeg, D.J. (1996). Psychological status among elderly people with chronic diseases: does type of disease play a part?. *Journal of Psychosomatic Research*, 40(5), p. 521-534.
- Penninx, B.W., Messier, S.P., Rejeski, W.J., Williamson, J.D., DiBari, M., Cavazzini, C., Applegate, W.B. and Pahor, M. (2001). Physical exercise and the prevention of disability in activities of daily living in older persons with osteoarthritis. *Archives of Internal Medicine*, 161(19), p. 2309-2316.
- Phaswana-Mafuya, N., Peltzer, K., Chirinda, W., Kose, Z., Hoosain, E., Ramlagan, S., Tabane, C. and Davids, A. (2013). Self-rated health and associated factors among older South Africans: evidence from the study on global ageing and adult health. *Global Health Action*, 6(1), p. 19880.
- Pignolo, R.J., Law, S.F. and Chandra, A. (2021). Bone aging, cellular senescence, and osteoporosis. *JBMR plus*, 5(4), p. 10488.
- Pollitzer, W.S., Anderson, J.J.B. (1989). Ethnic and genetic differences in bone mass: A review with a hereditary vs environmental perspective. *American Journal of Clinical Nutrition* 50, p. 1244–1259.
- Praneatpolgrang, S., Prasitwattanaseree, S. and Mahakkanukrauh, P. (2019). Age estimation equations using vertebral osteophyte formation in a Thai population: comparison and modified osteophyte scoring method. *Anatomy and Cell Biology*, 52(2), p. 149-160.
- Price, J.S., Waters, J.G., Darrah, C., Pennington, C., Edwards, D.R., Donell, S.T. and Clark, I.M. (2002). The role of chondrocyte senescence in osteoarthritis. *Aging cell*, 1(1), p. 57-65.
- Queen, R. (2017). Directing clinical care using lower extremity biomechanics in patients with

- ankle osteoarthritis and ankle arthroplasty. *Journal of Orthopaedic Research*, 35(11), p. 2345-2355.
- Rando, C. and Waldron, T. (2012). TMJ osteoarthritis: a new approach to diagnosis. *American Journal of Physical Anthropology*, 148(1), p. 45-53.
- Ravalli, S., Pulici, C., Binetti, S., Aglieco, A., Vecchio, M. and Musumeci, G. (2019). An overview of the pathogenesis and treatment of elbow osteoarthritis. *Journal of Functional Morphology and Kinesiology*, 4(2), p. 30.
- Retief, M. and Letšosa, R. (2018). Models of disability: A brief overview. *HTS Teologiese Studies/Theological Studies*, 74(1).
- Roberts, C. (1999). Disability in the Skeletal Record: Assumptions, Problems and Some Example. *Archaeological Review from Cambridge*, 15(2), p. 79-97.
- Roberts, S., Evans, H., Trivedi, J. and Menage, J. (2006). Histology and Pathology of the Human Intervertebral Disc. *The Journal of Bone and Joint Surgery*, 88, p. 10-14.
- Roddy, E. and Menz, H.B. (2018). Foot osteoarthritis: latest evidence and Developments. *Therapeutic Advances in Musculoskeletal Disease*, 10(4), p. 91-103.
- Rogers, J., Waldron, T., Dieppe, P. and Watt, I. (1987). Arthropathies in Palaeopathology: The Basis of Classification According to Most Probable Cause. *Journal of Archaeological Science*, 14(2), p. 179-193.
- Rogers, J. and Waldron, T. (2001). DISH and the monastic way of life. *International Journal of Osteoarchaeology*, 11(5), p. 357-365.
- Rogers, J., Shepstone, L. and Dieppe, P. (2004). Is Osteoarthritis a Systemic Disorder of Bone? *Arthritis and Rheumatism: Official Journal of the American College of Rheumatology*, 50(2), p. 452-457.
- Rojas-Sepúlveda, C., Ardagna, Y. and Dutour, O. (2008). Paleoepidemiology of vertebral degenerative disease in a Pre-Columbian Muisca series from Colombia. *American Journal of Physical Anthropology*, 135(4), p. 416-430.
- Rothschild, B.M. (1997). Porosity: a curiosity without diagnostic significance. *American Journal of Physical Anthropology*, 104(4), p. 529-533.
- Saha, S., Behnke, A., Oldewage-Theron, W., Mubtasim, N. and Miller, M. (2021). prevalence and factors associated with food insecurity among older adults in Sub-Saharan Africa: a systematic review. *Journal of Nutrition in Gerontology and Geriatrics*, 40(4), p. 171-196.
- Salaffi, F., Carotti, M., Stancati, A. and Grassi, W. (2005). Health-related Quality of Life in

- Older Adults with Symptomatic Hip and Knee Osteoarthritis: A Comparison with Matched Healthy Controls. *Aging Clinical and Experimental Research*, 17(4), p. 255-263.
- Sanchez-Lopez, E., Coras, R., Torres, A., Lane, N.E. and Guma, M. (2022). Synovial inflammation in osteoarthritis progression. *Nature Reviews Rheumatology*, 18(5), pp.258-275.
- Santuzzi, A.M. and Waltz, P.R. (2016). Disability in the workplace: A unique and variable identity. *Journal of Management*, 42(5), p. 1111-1135.
- Sarzi-Puttini, P. and Atzeni, F. (2004). New developments in our understanding of DISH (diffuse idiopathic skeletal hyperostosis). *Current Opinion in Rheumatology*, 16(3), p. 287-292.
- Sarzi-Puttini, P., Cimmino, M.A., Scarpa, R., Caporali, R., Parazzini, F., Zaninelli, A., Atzeni, F. and Canesi, B., (2005). Osteoarthritis: an overview of the disease and its treatment strategies. *In Seminars in Arthritis and Rheumatism*, 35(1), p. 1-10.
- Saunders, S.R. and DeVito, C. (1991). Subadult skeletons in the Raymond Dart anatomical collection: research potential. *Human Evolution*, 6(5), p. 421-433.
- Schatz, E., Gómez-Olivé, X., Ralston, M., Menken, J. and Tollman, S. (2012). The impact of pensions on health and wellbeing in rural South Africa: does gender matter? *Social Science and Medicine*, 75(10), p. 1864-1873.
- Schatz, E., Ralston, M., Madhavan, S., Collinson, M.A. and Gómez-Olivé, F.X. (2018). Living arrangements, disability and gender of older adults among rural South Africa. *The Journals of Gerontology: Series B*, 73(6), p. 1112-1122.
- Scheker, L.R. and Severo, A. (2001). Ulnar shortening for the treatment of early post-traumatic osteoarthritis at the distal radioulnar joint. *The Journal of Hand Surgery: British and European Volume*, 26(1), p. 41-44.
- Schober, P., Boer, C. and Schwarte, L.A. (2018). Correlation coefficients: appropriate use and interpretation. *Anesthesia and Analgesia*, 126(5), p. 1763-1768.
- Shakespeare, T. (1999). Commentary: Observations on Disability and Archaeology. *Archaeological Review from Cambridge*, 15(2), p. 99-101.
- Shakespeare, T. (2015). Disability research today. London: Routledge.
- Shakespeare, T. (2018). Power and prejudice: issue of gender, sexuality and disability. In *Disability and Society*. Routledge.
- Shankar, H., Scarlett, J.A. and Abram, S.E. (2009). Anatomy and pathophysiology of

- intervertebral disc disease. *Techniques in Regional Anesthesia and Pain Management*, 13(2), p. 67-75.
- Sharma, L., Song, J., Felson, D.T., Cahue, S., Shamiyeh, E. and Dunlop, D.D. (2001). The Role of Knee Alignment in Disease Progression and Functional Decline in Knee Osteoarthritis. *Journal of the American Medical Association*, 286(2), p. 188-195.
- Sharma, A., Kudesia, P., Shi, Q. and Gandhi, R. (2016). Anxiety and depression in patients with osteoarthritis: impact and management challenges. *Open access rheumatology: research and reviews*, 8, p. 103.
- Shin, E.K. and Osterman, A.L. (2008). Treatment of thumb metacarpophalangeal and interphalangeal joint arthritis. *Hand Clinics*, 24(3), p. 239-250.
- Shuttleworth, R. and Meekosha, H. (2017). Accommodating critical disability studies in bioarchaeology. In *Bioarchaeology of Impairment and Disability*. Springer, Cham.
- Sinusas, K. (2012). Osteoarthritis: diagnosis and treatment. *American Family Physician*, 85(1), p. 49-56.
- Siris, E.S., Miller, P.D., Barrett-Connor, E., Faulkner, K.G., Wehren, L.E., Abbott, T.A., Berger, M.L., Santora, A.C. and Sherwood, L.M. (2001). Identification and Fracture Outcomes of Undiagnosed Low Bone Mineral Density in Postmenopausal Women: Results from the National Osteoporosis Risk Assessment. *Journal of the American Medical Association*, 286(22), p. 2815-2822.
- Snodgrass, J.J. (2004). Sex differences and aging of the vertebral column. *Journal of Forensic Sciences*, 49(3), p. 1-6.
- Song, S., Lam, E.W.F., Tchkonja, T., Kirkland, J.L. and Sun, Y. (2020). Senescent Cells: Emerging Targets for Human Aging and Age-related Diseases. *Trends in Biochemical Sciences*, 45(7), p. 578-592.
- Srikanth, V.K., Fryer, J.L., Zhai, G., Winzenberg, T.M., Hosmer, D. and Jones, G. (2005). A meta-analysis of sex differences prevalence, incidence and severity of osteoarthritis. *Osteoarthritis and Cartilage*, 13(9), p. 769-781.
- Stamm, T.A., Pieber, K., Crevenna, R. and Dorner, T.E. (2016). Impairment in the activities of daily living in older adults with and without osteoporosis, osteoarthritis and chronic back pain: a secondary analysis of population-based health survey data. *BMC Musculoskeletal Disorders*, 17(1), p. 1-10.
- Stats, S.A. (2011). Statistics South Africa. *Formal census*.
- Steckel, R.H., Sciulli, P.W. and Rose, J.C. (2002a). A Health Index from Skeletal

- Remains, In: Steckel, R.H. and Rose, J.C. eds. *The Backbone of History: Health and Nutrition in the Western Hemisphere*.
- Steckel, R. H., Rose, J. C., Larsen, C. S., and Walker, P. L. (2002b). Skeletal health in the Western Hemisphere from 4000 BC to the present. *Evolutionary Anthropology*, 11, p. 142-155.
- Steultjens, M.P., Dekker, J., Van Baar, M.E., Oostendorp, R.A. and Bijlsma, J.W. (2001). Muscle strength, pain and disability in patients with osteoarthritis. *Clinical Rehabilitation*, 15(3), p. 331-341.
- Steyn, M. (2019). The Raymond A. Dart collection as a mirror of society: The case of Tuberculosis. *Adler Museum Bulletin*.
- Steyn, M., van der Merwe, A.E. and Meyer, A. (2021). Infectious disease and nutritional deficiencies in early industrialized South Africa. *International Journal of Paleopathology*, 33, p. 128-136.
- Swagerty Jr, D.L. and Hellinger, D. (2001). Radiographic assessment of osteoarthritis. *American Family Physician*, 64(2), p. 279-287.
- Swain, S., Sarmanova, A., Coupland, C., Doherty, M. and Zhang, W. (2020). Comorbidities in osteoarthritis: a systematic review and meta-analysis of observational studies. *Arthritis Care and Research*, 72(7), p. 991-1000.
- Taitz, C. (1999). Osteophytosis of the cervical spine in South African blacks and whites. *Clinical Anatomy*, 12(2), p. 103-109.
- Tallents, R.H., Macher, D.J., Kyrkanides, S., Katzberg, R.W. and Moss, M.E. (2002). Prevalence of missing posterior teeth and intraarticular temporomandibular disorders. *The Journal of Prosthetic Dentistry*, 87(1), p. 45-50.
- Tamura, T., Otaka, Y., Konno, S., Sadashima, K., Tomatsu, T. and Machida, S. (2016). The impaired balance systems identified by the BESTest in older patients with knee osteoarthritis. *The Journal of Injury, Function and Rehabilitation*, 8(9), p. 869-875.
- Tilley, L., and Oxenham, M. F. (2011). Survival against the odds: Modeling the social implications of care provision to seriously disabled individuals. *International Journal of Paleopathology*, 1(1), p. 35-42.
- Tilley, L. (2012). The bioarchaeology of care. *The SAA Archaeological Record*, 12(3), p. 39-41.
- Tilley, L. and Cameron, T. (2014). Introducing the Index of Care: A Web-based Application

- Supporting Archaeological Research Into Health-related Care. *International Journal of Paleopathology*, 6, p. 5-9.
- Tilley, L. (2015). Theory and Practice in the bioarchaeology of care. New York: Springer.
- Tomita, A. and Burns, J.K. (2013). Depression, disability and functional status among community-dwelling older adults in South Africa: evidence from the first South African National Income Dynamics Study. *International Journal of Geriatric Psychiatry*, 28(12), p. 1270-1279.
- UPIAS. (1976). Fundamental Principles of Disability. London: Union of the Physically Impaired Against Segregation.
- Usenbo, A., Kramer, V., Young, T. and Musekiwa, A. (2015). Prevalence of arthritis in Africa: a systematic review and meta-analysis. *PloS one*, 10(8), p. 1-19.
- Utsinger, P.D. (1985). Diffuse idiopathic skeletal hyperostosis. *Clinics in Rheumatic Diseases*, 11(2), p. 325-351.
- Van der Esch, M., Steultjens, M., Knol, D.L., Dinant, H. and Dekker, J. (2006). Joint laxity and the relationship between muscle strength and functional ability in patients with osteoarthritis of the knee. *Arthritis Care and Research*, 55(6), p. 953-959.
- Van der Merwe, A.E., Işcan, M.Y. and L'Abbè, E.N. (2006). The pattern of vertebral osteophyte development in a South African population. *International Journal of Osteoarchaeology*, 16(5), p. 459-464.
- Van der Merwe, A.E., Morris, D., Steyn, M. and Maat, G.J.R. (2010). The history and health of a nineteenth-century migrant mine-worker population from Kimberley, South Africa. *The South African Archaeological Bulletin*, p. 185-195.
- Van Valburg, A.A., Van Roermund, P.M., Marijnissen, A.C.A., Van Melkebeek, J., Lammens, J., Verbout, A.J., Lafeber, F.P.J.G. and Bijlsma, J.W.J. (1999). Joint distraction in treatment of osteoarthritis: a two-year follow-up of the ankle. *Osteoarthritis and Cartilage*, 7(5), p. 474-479.
- Vergunst, R., Swartz, L., Hem, K.G., Eide, A.H., Mannan, H., MacLachlan, M., Mji, G., Braathen, S.H. and Schneider, M. (2017). Access to Health Care for Persons with Disabilities in Rural South Africa. *BMC Health Services Research*, 17(1), p. 1-8.
- Verlaan, J.J., Oner, F.C. and Maat, G.J.R. (2007). Diffuse idiopathic skeletal hyperostosis in ancient clergymen. *European Spine Journal*, 16, p. 1129-1135.
- Waldron, T. and Rogers, J. (1991). Inter-observer variation in coding osteoarthritis in human skeletal remains. *International Journal of Osteoarchaeology*, 1(1), p. 49-56.

- Waldron, T. (1997). Osteoarthritis of the hip in past populations. *International Journal of Osteoarchaeology*, 7(2), pp.186-189.
- Waldron, T. (2009) *Palaeopathology*, Cambridge: Cambridge University Press.
- Waldron, T. (2019). Joint disease. In Ortner's identification of pathological conditions in human skeletal remains. Academic Press.
- Walker, P.L., Bathurst, R.R., Richman, R., Gjerdrum, T. and Andrushko, V.A. (2009). The causes of porotic hyperostosis and cribra orbitalia: A reappraisal of the iron-deficiency-anemia hypothesis. *American Journal of Physical Anthropology*, 139(2), p. 109-125.
- Wang, Q., Rozelle, A.L., Lepus, C.M., Scanzello, C.R., Song, J.J., Larsen, D.M., Crish, J.F., Bebek, G., Ritter, S.Y., Lindstrom, T.M. and Hwang, I. (2011). Identification of a central role for complement in osteoarthritis. *Nature Medicine*, 17(12), p. 1674-1679.
- Wang, C., Pu, R., Li, Z., Ji, L., Li, X., Ghose, B., Huang, R. and Tang, S. (2019). Subjective health and quality of life among elderly people living with chronic multimorbidity and difficulty in activities of daily living in rural South Africa. *Clinical Interventions in Aging*, p. 1285-1296.
- Wang, X., Zhang, J.N., Gan, Y.H. and Zhou, Y.H. (2015). Current understanding of pathogenesis and treatment of TMJ osteoarthritis. *Journal of Dental Research*, 94(5), p. 666-673.
- Watanabe, S. and Terazawa, K. (2006). Age estimation from the degree of osteophyte formation of vertebral columns in Japanese. *Legal medicine*, 8(3), p. 156-160.
- Watkins, R. (2012). Variation in health and socioeconomic status within the W. Montague Cobb skeletal collection: Degenerative joint disease, trauma and cause of death. *International Journal of Osteoarchaeology*, 22(1), p. 22-44.
- Watson, N. (2002). Well, I know this is going to sound very strange to you, but I don't see myself as a disabled person: Identity and disability. *Disability and Society*, 17(5), p. 509-527.
- Waxenbaum, J.A., Reddy, V., Williams, C. and Futterman, B., 2023. Anatomy, back, lumbar vertebrae. *StatPearls Publishing*.
- Weiss, K.E. and Jurmain, R. (2007). Osteoarthritis revisited: a contemporary review of aetiology. *International Journal of Osteoarchaeology*, 17(5), p. 437-450.
- Weiss, K.E. and Rodner, C.M. (2007). Osteoarthritis of the wrist. *The Journal of Hand Surgery*, 32(5), p. 725-746.

- White, A.A. and Panjabi, M.M. (1978). The basic kinematics of the human spine: a review of past and current knowledge. *Spine*, 3(1), p. 12-20.
- White, T.D. and Folkens, P.A. (2005). The human bone manual. Elsevier.
- Wong, S.H.J., Chiu, K.Y. and Yan, C.H. (2016). osteophytes. *Journal of Orthopaedic Surgery*, 24(3), p. 403-410.
- World Health Organization (2003). International Classification of Functioning Disability and Health. World Health Organization. Accessed 3 May 2022.
- World Health Organization. (2007). International Classification of Functioning, Disability, and Health: Children and Youth Version: ICF-CY. World Health Organization.
- World Health Organization and the World Bank. (2011). World Report on Disability Geneva: World Health Organization. Accessed 1 June 2021.
- Wright NM, Renault J, Willi S, Veldhuis JD, Pandey JP, Gordon L, Key LL, Bell NH. (1995). Greater secretion of growth hormone in black than in white men: Possible factor in greater bone mineral density - A clinical research center study. *Journal of Clinical Endocrine Metabolism* 80, p. 2291–2297.
- Wrisdale, L., Mokoena, M.M., Mudau, L.S. and Geere, J.A. (2017). Factors that impact on access to water and sanitation for older adults and people with disability in rural South Africa: An occupational justice perspective. *Journal of Occupational Science*, 24(3), p. 259-279.
- Xavier Gómez-Olivé, F., Thorogood, M., Clark, B.D., Kahn, K. and Tollman, S.M. (2010). Assessing health and well-being among older people in rural South Africa. *Global Health Action*, 3(1), p. 2126.
- Yaya, S., Idriss-Wheeler, D., Sanogo, N.D.A., Vezina, M. and Bishwajit, G. (2020). Self-reported activities of daily living, health and quality of life among older adults in South Africa and Uganda: a cross sectional study. *BMC Geriatrics*, 20, p. 1-11.
- Young, M. (2016). Private vs. Public Healthcare in South Africa. Honors Theses.
- Zedda, N., Bramanti, B., Gualdi-Russo, E., Ceraico, E. and Rinaldo, N. (2021). The biological index of frailty: A new index for the assessment of frailty in human skeletal remains. *American Journal of Physical Anthropology*, 176(3), p. 459-473.

10. Appendix A

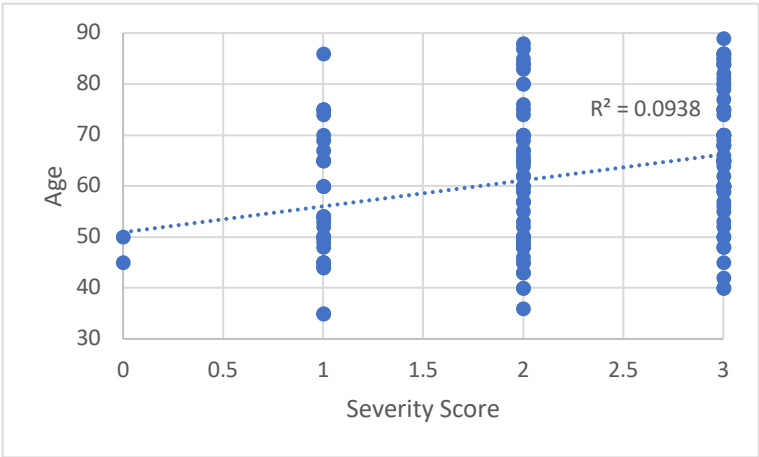


Figure 40. Age vs. DJD score correlation for the shoulder joint

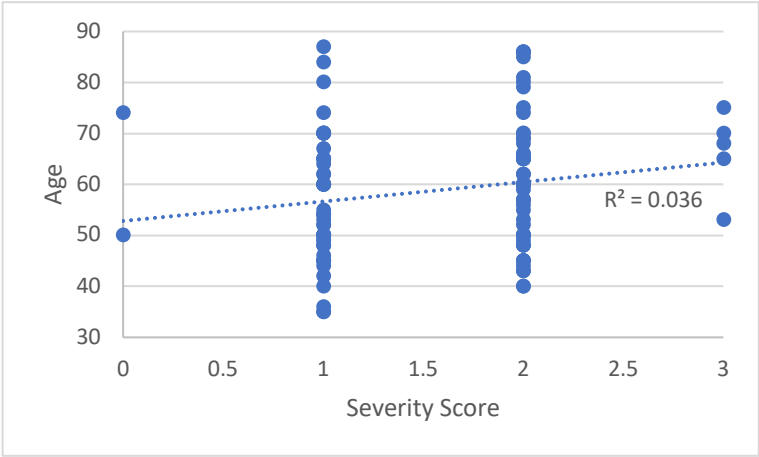


Figure 41. Age vs. DJD score correlation for the wrist joint

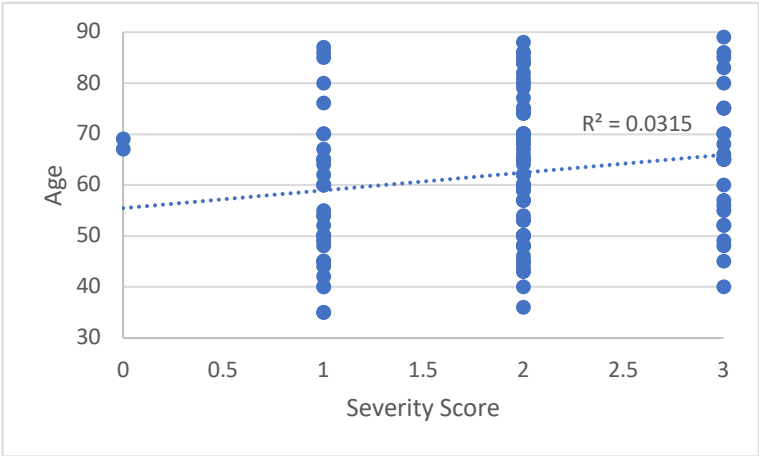


Figure 42. Age vs. DJD score correlation for the finger joint

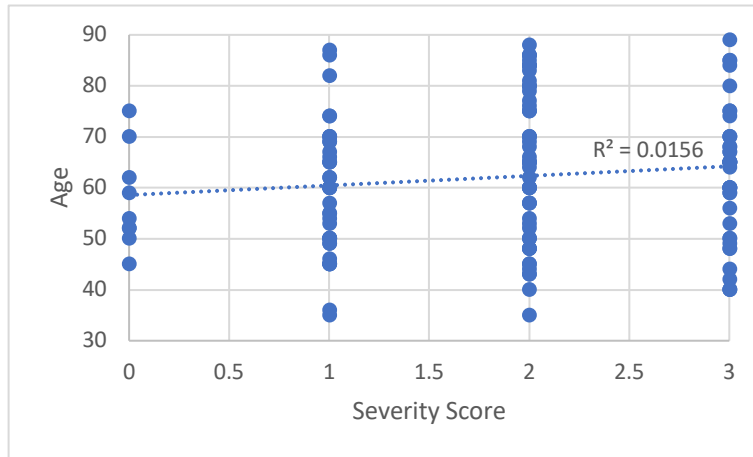


Figure 43. Age vs. DJD score correlation for the hip joint

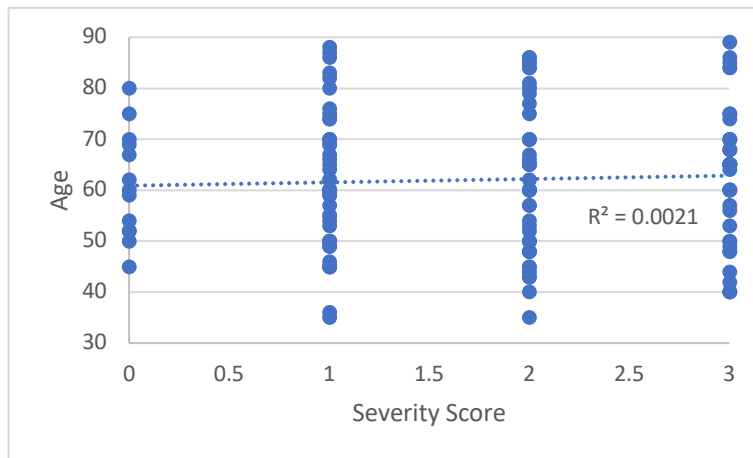


Figure 44. Age vs. DJD score correlation for the knee joint

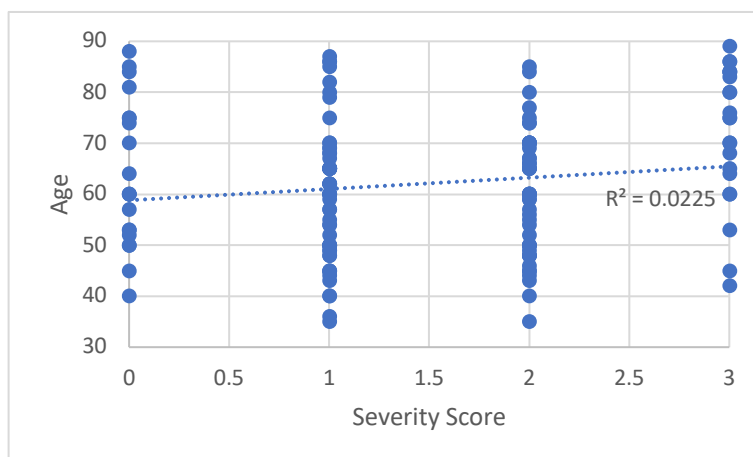


Figure 45. Age vs. DJD score correlation for the toe joint

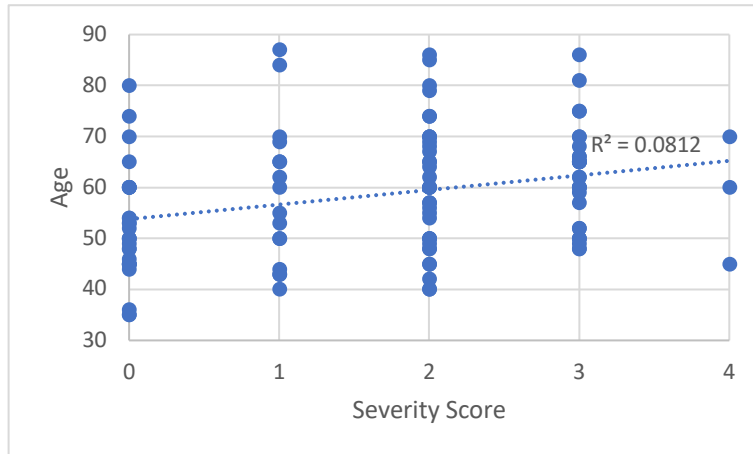


Figure 46. Age vs. DJD score correlation for the cervical vertebral joint

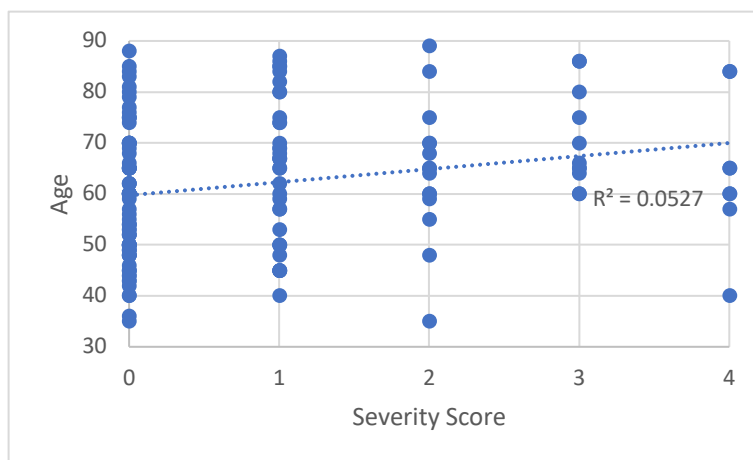


Figure 47. Age vs. DJD score correlation for the thoracic vertebral joint

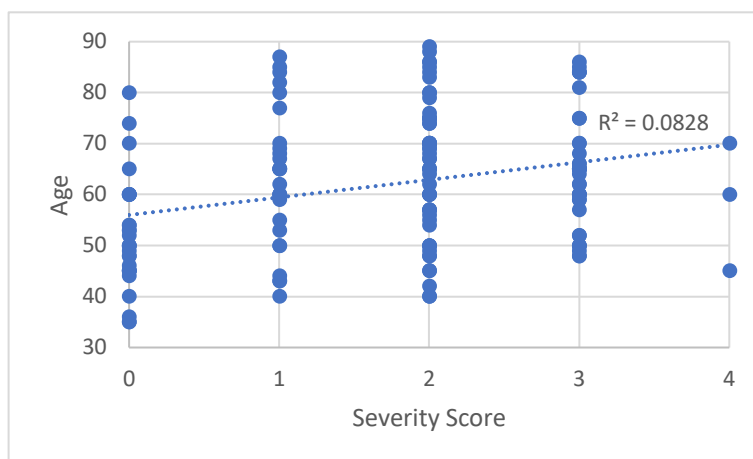


Figure 48. Age vs. DJD score correlation for the lumbar vertebral joint