The development of grading criteria and investigation of single rater test-retest reliability of selected floor sitting postures

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DECLARATION

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This Research Project entitled “The development of grading criteria and investigation of single rater test-retest reliability of selected floor sitting postures” is submitted in partial fulfilment for the requirements for the Unitec degree of Masters of Osteopathy

Candidate’s Declaration:

I confirm that:

- This Research Project represents my own work;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.
  Research Ethics Committee Approval Number: 2010-1024

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ABSTRACT

Background and objectives
The use of floor sitting postures may provide an alternative to regional orthopaedic examination for evaluation of the musculoskeletal system. No research has yet been conducted on the utility of evaluating floor sitting postures as an indicator of musculoskeletal function. The aims of this study were to: 1) develop grading criteria for floor sitting postures; 2) investigate single rater test-retest reliability of floor sitting postures between sessions.

Methods
Part 1 - Development of grading criteria: An iterative process of development and review was undertaken to select appropriate floor sitting postures; identify performance variables for each posture; describe and refine criteria of performance quality; and develop a grading scale to evaluate the quality of performance for each posture.

Part 2 - A repeated measures design was employed to investigate single rater test-retest reliability of the postures. A sample of 33 healthy participants (n=23F, n=10M) were recruited from the general population. Participants attended two sessions within a 7 to 14-day interval. Anatomical landmarks were marked on each participant with titanium dioxide and self-adhesive markers. Participants performed 3-trials of six defined floor sitting postures in each session. Postures were recorded using digital video in two views; anterior and lateral. Still frames for each posture were captured and analysed. Postural dimensions were measured on each frame. The mean of the postural dimensions for 3-trials of each session was used to analyse the reliability of posture between sessions.

Results
Part 1 - The final grading criteria included six variations of floor sitting postures. A grading system was developed using a 3-6 point ordinal scale.

Part 2 - Data from 25 participants (n=17F, n=8) was used for analysis by a single rater of test-retest reliability. Inter-session reliability was calculated for each posture dimension using intra-class correlation coefficients (ICC). Postural dimensions for four of the six postures demonstrated high reliability ranging from ‘very high’ (ICC = 0.87; 95% CI 0.71 to 0.94) to ‘nearly perfect’ (ICC = 0.97; 95% CI 0.94 to 0.99). The Straight Leg Sit postural angle of dorsiflexion demonstrated ‘low’ reliability (ICC = 0.67; 95% CI 0.25 to 0.85). The Low Kneel postural angle of hip flexion demonstrated ‘moderate reliability’ (ICC = 0.71; 95% CI 0.37 to 0.87).

Conclusion
A set of grading criteria to evaluate the quality of a defined group of floor sitting postures was developed. Participants in this study demonstrated a reasonable level of consistency in achieving postures between two sessions over a 7 to 14-day period. Observer reliability of grading floor sitting postures was not part of this study and needs to be investigated to determine the clinical utility of the grading criteria.

Keywords: posture; movement; functional movement; physical examination; musculoskeletal pain; musculoskeletal disorders; ancestral health; screening
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INTRODUCTION TO THESIS

The following thesis is structured in three sections:

Section I. Literature Review
Section II. Manuscript
Section III. Appendices

Section I provides a background of the physical assessment of posture and builds a rationale for the empirical study supported in Section II of the thesis.

Section I includes an overview of the background and relevant literature with specific consideration of posture assessment. Topics covered in Section I include an introduction to an ancestral perspective on health. The following sub-section reviews musculoskeletal disorders and their associated risk factors. Controversies surrounding the relationship between posture and pain are discussed in detail in the next sub-section, thereby informing the subsequent discussion of posture assessment. The sub-section of posture assessment outlines the conventional orthopaedic approach to musculoskeletal assessment and leads to a discussion of a ‘global’ and ‘functional’ approach to musculoskeletal evaluation. The concept of screening posture and movement, in particular ‘functional movement’ is also reviewed.

An approach to ‘functional’ methods of physical assessment using floor sitting postures is proposed. A rationale for the use of floor sitting postures as a method of assessing the quality of posture is described. Possible limitations of using floor sitting postures are considered. Gaps in research are outlined and these provide the basis for the Aims addressed in Section II of the thesis.
SECTION I.

LITERATURE REVIEW
INTRODUCTION

This review provides an overview of an ‘ancestral perspective’ on health in relation to lifestyle changes over an evolutionary timescale that may contribute to the development of musculoskeletal disorders. Subsequent sections explain the possible genesis of postural aberrations and musculoskeletal pain. The assessment and ‘screening’ of the musculoskeletal system through posture and movement will be discussed, with attention to the concept of ‘functional movement’. Finally, a physical assessment method concerning ‘screening’ the quality of static floor sitting postures is discussed.

1. ANCESTRAL PERSPECTIVE ON HEALTH

An ‘ancestral perspective’ on health has been proposed as a robust framework in which to consider issues of health and longevity ("Ancestral Health Symposium," 2012; Eaton, Konner, & Shostak, 1988). This framework draws on the principles of evolutionary biology in relation to human evolution (Cordain et al., 2005; O'Keefe, Vogel, Lavie, & Cordain, 2011). The environment and lifestyle in which we live today differs dramatically in many respects from those of our hunter-gatherer ancestors, but most saliently to this discussion it differs in terms of our diet, type and amount of physical activity, and the way in which we interact and communicate.
1.1. **Evolutionary time periods**

It has been proposed that the human genome, environment and lifestyle have been refined and gradually moulded through many generations (Booth, Chakravarthy, & Spangenburg, 2002). Humans have evolved through an evolutionary timescale from the Palaeolithic era (prehistoric time of 2.5 million years ago until 10,000 years ago) of hunter-gatherers to the current Information age. Many researchers (Booth, Chakravarthy, & Spangenburg, 2002; Cordain et al., 2005; Eaton & Eaton, 1999; Gary, 2008; Holth, Werpen, Zwart, & Hagen, 2008; O'Keefe et al., 2011) are interested in the lifestyle changes that have occurred since the time of the hunter-gatherers through historical time periods. Revolutions of human history that followed the Paleolithic era were the Agricultural (circa 16th-19th century), Industrial (circa 17th-19th century) and the present Technological or Information Revolution (circa 19th century-present) (Walker, Walker, & Adam, 2003).

1.2. **Modern lifestyle factors and ill-health**

The advances in communication and technology which are ubiquitous in modern lifestyle have been beneficial in many respects, but have also brought about their own set of less beneficial influences on human health and the musculoskeletal system. An obvious characteristic of modern lifestyle is the growing level of physical inactivity that has been observed in parallel to technological advances (Chau, van der Ploeg, Merom, Chey, & Bauman, 2011; de León et al., 2007). This is in sharp contrast with the obligate physically active hunter-gatherer lifestyle (Eaton & Eaton, 1999).

Physical inactivity has been associated with elevated prevalence of morbid systemic disease and musculoskeletal disorders (Raynor, Bond, Freedson, & Sisson, 2012). Evidence suggests that at least 60% of the general population are failing to achieve the World Health Organisation’s minimum recommendation of 30-minutes of moderate-intensity physical activity daily (de León et al., 2007; World Health Organisation, 2010). The link between physical inactivity and health morbidity has been convincingly demonstrated in the literature. Chronic diseases such as heart disease (Dunstan, Thorp, & Healy, 2011), type II diabetes (Grøntved & Hu, 2011), and obesity (Thorp, Owen, Neuhaus, & Dunstan, 2011), are all known to be highly associated with physical inactivity and sedentary behaviours (Raynor et al., 2012). Along with systemic diseases, physical
inactivity has also been linked to musculoskeletal disorders (Landmark, Romundstad, Borchgrevink, Kaasa, & Dale, 2011; Troup & Videman, 1989).

1.3. Potential mismatch of the human genome to modern lifestyle

The basic science of evolutionary biology is continually being researched and developed, building on the stable foundations of Darwin’s theory of natural selection (Meagher & Futuyma, 2001). Genetic variants of the human genome, through several generations, have been selected for through prevailing conditions and adaptations of human survival (Barbujani & Colonna, 2010; Booth, Chakravarthy, & Spangenberg, 2002). It has been suggested by many researchers that close to 100% of our human biology was naturally selected during the time period in which our ancestors lived as hunter-gatherers (Booth, Chakravarthy, & Spangenberg, 2002; Cordain et al., 2005; Eaton & Eaton, 1999; Meagher & Futuyma, 2001; Nesse et al., 2010). The human genome is suggested to have changed very little since the Paleolithic era (2.5 million years ago), and still resembles that of human ancestors who lived a hunter-gatherer lifestyle which is radically different to the modern lifestyle prevalent in developed countries (Barbujani & Colonna, 2010; Cordain et al., 2005; O'Keefe et al., 2011; Pritchard, Pickrell, & Coop, 2010). The central hypothesis of the ancestral perspective on health is that the changes in response to agriculture, industrialisation and technology have happened too rapidly for appropriate adaptation of the human genome (Cordain et al., 2005; Eaton & Eaton, 2003; O'Keefe et al., 2011). Therefore, potential mismatch of the human genome and our current lifestyle poses increased risk of ill-health.

Using an evolutionary perspective on health many researchers (Cordain et al., 2005; Eaton et al., 1988; O'Keefe et al., 2011; O'Keefe & Cordain, 2004), and other proponents in the public domain ("Ancestral Health Symposium," 2012; Le Corre, 2012; Sisson, 2010; Taubes, 2008; Wolf, 2012), propose that the modern lifestyle is not biologically compatible with the human genome and that the ancestral lifestyle may be more genetically suitable (Archer & Blair, 2011; Cordain et al., 2005; Eaton et al., 1988; O'Keefe et al., 2011; Williams & Nesse, 1991). Preliminary evidence suggests that this mismatch between the slow changing human genome and the rapid advances of our current environment, is playing a substantial role in the near epidemic rates of
the many so called diseases of the developed world including obesity, cardiovascular disease and type II diabetes (O’Keefe & Cordain, 2004; World Health Organisation, 2000).

It has been proposed by researchers that hunter-gatherers were ‘healthier’ than modern humans, even though they had a lower life expectancy (life expectancy 35-50 years) than their modern counterparts (Archer & Blair, 2011; Cordain et al., 2005; Larsen, 2006; O’Keefe & Cordain, 2004; Tooby & Cosmides, 1990). In suggesting that hunter-gatherers are ‘healthier’ than typical modern humans the indices of health that are cited include superior aerobic fitness resulting in a body composition with higher levels of lean tissue, lower blood pressure and cholesterol levels, reduced cardiovascular complications, and cancer (Eaton & Eaton, 1999). Despite common indices of health appearing to be superior for hunter-gatherers, a lower life expectancy is explained by exposures experienced by the hunter-gatherers. These exposures include: climatic challenges; risk of accident and trauma from foraging; predation; infectious diseases from nutrient and pathogens stress without the benefit of modern medical intervention such as antibiotics (Hill, Hurtado, & Walker, 2007).

1.4. Hunter-gatherer lifestyle

Hunter-gatherers had a physical lifestyle in which the procurement of basic necessities for food and shelter required high levels of physical activity. Routine daily activities of hunter-gatherers whether it be hunting, gathering food, fuel and water, tool making and travelling by foot for some distance to fulfil their daily needs for food and shelter, all required high levels of physical activity (Eaton & Eaton, 2003; O’Keefe et al., 2011). Hunter-gatherers generated high amounts of energy expenditure when compared to modern humans (Eaton et al., 1988). The diet of hunter-gatherers was exclusively uncultivated vegetables and wild game meat (O’Keefe et al., 2011). Anthropological evidence demonstrates, in comparison to modern humans, that the skeletal remains of hunter-gatherer people showed marked bony prominences reflecting the likely size and strength of skeletal muscle and increased cortical thickness of long bone shafts (Eaton et al., 1988).
1.5. *Agricultural Revolution*

On an evolutionary time scale, the rate of environmental and lifestyle change occurring from the period of the Agricultural Revolution (circa 16th-19th century) has been rapid, and the rate of change has continued to increase in the subsequent Industrial and Information Revolutions (Popkin, 1999). The Agricultural Revolution is characterised by the introduction of food cropping and the domestication of animals, which provided a more predictable source of food among developing communities. Furthermore, the development of communities and defined areas where people built their livelihoods resulted in a rise of trade and economic activity. The advent of agriculture meant that food and other commodities were readily available compared to that of hunting and gathering, thus requiring shorter distances of travel, and less physical exertion for daily living.

Physical activity declined with the agricultural way of life due to regionalisation of communities and decreased workload involved in planting, tending and harvesting crops compared to hunting and gathering. Larsen (2006) and Mummert, Esche, Robinson, and Armelagos (2011) suggest that hunter-gatherer populations experienced higher prevalence of osteoarthritis with more cortical bone strength and density, than that of the agricultural population. According to these researchers the evidence indicates that the hunter-gatherers had a more physically demanding workload and lifestyle. However, other factors should also be considered in the higher prevalence of osteoarthritis such as terrain and regional diet that would affect each hunter-gatherer population differently (Pérez-López, Chedraui, Haya, & Cuadros, 2009). Therefore, higher prevalence of osteoarthritis in hunter-gatherers cannot be attributed to physical activity alone as a causative factor.

The health implications of an agricultural way of life have been explored by several authors (Cordain et al., 2005; Larsen, 2006; Mummert et al., 2011; Walker et al., 2003). It has been argued that although more readily available, the nutritional value of domesticated animals and plants was probably less than uncultivated plants and game meat consumed by the hunter-gatherer. The nutritional value and quality of foods has decreased over the generations and have shown adverse effects on the health of people in both developing and developed countries (Cordain et al., 2005; Dwyer, 2006; O’Keefe, Cordain, 2004; Pérez-López et al., 2009; Stover & Caudill, 2008; Taubes, 2008).
The Aboriginal Australian hunter-gatherers have been subject to a significant amount of research as an accessible population who, until recently, have maintained a hunter-gatherer lifestyle (Burke et al., 2007; O’Dea, 2005). Aboriginal people living outside the influence of western culture consumed a diet that consisted of a wide variety of animal and plant sources which was mostly composed of a macro-nutrient ratio of 50% protein, 40% fat, 10% carbohydrate. This is in dramatic contrast to macro-nutrient ratio to diets of modern human and hunter-gatherers who have adapted to a modern lifestyle (Ströhle & Hahn, 2011; Walker et al., 2003).

The Aboriginal hunter-gatherer diet appeared to change as European settlement became increasingly prevalent. Paucity of hunting and gathering and a change in the Aboriginal diet to include foreign foods such as flour, sugar and processed meat appeared to deprive the Aboriginal hunter-gatherer of essential protein, vitamins and minerals, leading to nutritional deficiencies and ill-health (O’Dea, 2005). Aboriginal hunter-gatherers more recently adapting to western culture, consume a diet of low nutritional value consisting of increased amounts of low quality fats and oils and simple carbohydrates (e.g., bread), along with decreased levels of physical activity and behavioural changes such as excessive cigarette smoking and alcohol consumption. This change of lifestyle from the hunter-gatherer to western or modern lifestyle is suggested to have adverse effects on health such as chronic disease (Burke et al., 2007). The prevalence of chronic disease such as cardiovascular disease and type II diabetes in Aboriginal younger age groups of 25-45 year olds are 10 times higher than the national rates of non-Aboriginal people (O’Dea, 2005).

Radical lifestyle changes from the hunter-gatherer to agricultural and modern lifestyle have adverse effects on health. The modern lifestyle differs significantly from the hunter-gatherer lifestyle where food is abundant, readily available and of low-nutritional value in conjunction with decreased levels of physical activity.
1.6.  **Industrial Revolution**

The Industrial Revolution (circa 17th-19th century) introduced mechanised transport, and more sophisticated forms of agriculture, manufacturing, mining and technology than the Agricultural Revolution. The Industrial Revolution resulted in substantial economic development and increasing opportunities for work, education and leisure. The initial effect of these advances included improvements in public health; increases in the amount, quality, and variety of food; and increased longevity with these effects combined (Garabed, 2006). Many authors suggest that the rise in cardiovascular disease and obesity is associated with overabundance of accessible food, coupled with reduced activity (Farber & Páez, 2011; Samimi, Mohammadian, & Madanizadeh, 2009; Wener & Evans, 2011). Furthermore, the development of the economy came with the growth of cities and towns, forcing people into confined spaces of living and rendered their daily activities facile in terms of energy expenditure (Popkin, 1999).

1.7.  **Information Revolution**

The Information Revolution (circa 19th century-present) brought global technological, social and economic shifts such as the computer and internet, which radically changed communication and networking. Changes in the workplace since the Industrial Revolution can be related to the advances of information and computer technology. A ‘knowledge-based economy’ has almost replaced low and semi-skilled physical labour, due to advances in mechanisation (Cazzavillan & Olszewski, 2011; Kenney, 1996). The term ‘knowledge-based economy’ has been used to describe an economy that is “directly based on the production, distribution and use of knowledge and information” (Sabau, 2010). ‘Knowledge workers’ are not new but an emerging workforce due to the increasing need for processing information and data since the Industrial Revolution, and are considered to be people who “think for a living” (Cortada, 1998a). Knowledge workers are common in medicine and health, business, law, engineering, information technology, office administration and teaching professions (Cortada, 1998b).

One of the cardinal features of contemporary workplace settings is that of computer workstations (Graf, Guggenbühl, & Krueger, 1995). Some authors (Chau et al., 2011; de León et al., 2007; Dunstan et al., 2011; Raynor et al., 2012) suggest that physical inactivity at work and leisure, coupled with sitting at a computer workstation for most of the day can contribute to
musculoskeletal disorders and adverse effects on health. This physical inactivity observable in the modern workplace is also apparent in leisure time, with changes in the pattern of leisure associated with the proliferation of technological advances in multimedia, television and computer use (Booth, Chakravarthy, Gordon, & Spangenburg, 2002; Kenworthy & Laube, 1999).

In summary, the human genome may not be adapted to the modern lifestyle and this mismatch may contribute to ill-health. Many factors such as physical inactivity and poor diet can be attributable to the rise of chronic disease and musculoskeletal disorders. The development of musculoskeletal disorders will be discussed in the next sub-section.
2. **MUSCULOSKELETAL DISORDERS**

2.1. *Modern lifestyle and musculoskeletal disorders*

Modern lifestyle attributes such as physical inactivity, high workplace demands of productivity and efficiency have been associated with musculoskeletal disorders (Dempsey & Mathiassen, 2006). Repetitive tasks and computer use are among some of the common modern workplace demands and are recognised as being risk factors that increase the likelihood of developing musculoskeletal disorders (Holth et al., 2008; Kausto et al., 2011; Ortiz-Hernández, Tamez-González, Martínez-Alcántara, & Méndez-Ramírez, 2003).

In many countries musculoskeletal disorders are highly prevalent and are linked to substantial health care costs, high levels of health resource utilisation, time off work (Harcombe, McBride, Derrett, & Gray, 2009) and health related disability (Harkness, Macfarlane, Silman, & McBeth, 2005; Jiménez-Sánchez et al., 2010; Widanarko et al., 2011). Musculoskeletal disorders include a wide range of inflammatory and degenerative conditions that involve the osteoarticular and muscular system, affecting either the upper or the lower extremity, or the axial skeleton (Lanfranchi & Duveau, 2008). According to the World Health Organisation (2009) musculoskeletal disorders are often associated with pain and functional impairment, which are mostly transitory and episodic in nature, but can become chronic and disabling. There are many risk factors that may influence the likelihood of the development of musculoskeletal disorders.

2.2. *Risk factors for the development of musculoskeletal disorders*

Numerous risk factors associated with musculoskeletal disorders arise from work, domestic and leisure environments. According to Bogduk (2006) risk factors can be defined as, “features evident in individuals before they develop back pain and which are statistically associated with a higher risk of developing back pain in the future.” Although, this is a sound definition, cause and effect relationships of risk factors to musculoskeletal pain is difficult to investigate. Therefore, risk factors may be influential on back pain or any musculoskeletal disorder at different phases including genesis, maintenance and recovery from musculoskeletal pain or dysfunction. There is
substantial evidence that musculoskeletal disorders are strongly work related (Burton, Kendall, Pearce, Birrell, & Bainbridge, 2009) but controversy exists about the magnitude of risk attributable to various factors, and whether the risk factors are correlative and/or causative of musculoskeletal disorders (Punnett & Wegman, 2004).

The term ‘work related musculoskeletal disorders’ refers to, “musculoskeletal disorders that are products of accumulated or repeated traumas, likely to arise from work activities and environments that are prevalent in developed countries” (Ortiz-Hernández et al., 2003). To assess musculoskeletal disorders many authors (Alonso, 2004; Engel, 1997; Nicholas, 2008) believe that the Biopsychosocial Model should be utilised by clinicians, as there is an increasing body of literature linking physical, psychological and individual risk factors with musculoskeletal disorders (da Costa & Vieira, 2010; Kausto et al., 2011).

The Biopsychosocial Model was first conceptualised by Engel (1997) who regarded ill-health as being composed of the interrelation of the biological/physical, psychological/personal and social factors (social context, pressures and constraints on behaviour and functioning) (Alonso, 2004; Engel, 1997; Nicholas, 2008; Waddell & Burton, 2005). The Biopsychosocial Model is widely used in healthcare to understand and consider the spectrum of potential factors that may be influencing health status.

Consistent with the Biopsychosocial Model, risk factors for musculoskeletal disorders can be conveniently divided into three categories: 1) Psychosocial; 2) Individual or genetic; and 3) Physical or biomechanical. Each of these factors will be discussed in the next sections.

### 2.3. **Psychosocial risk factors associated with the development of musculoskeletal disorders**

Psychosocial factors can be explained as being non-physical aspects of an individual’s environment (Deeney & O'Sullivan, 2009) and have been particularly related to the workplace (Burton et al., 2009). Stress, attitude, anxiety, depression, fear avoidance beliefs are examples of psychosocial factors; and also encompass psychosocial work stressors such as job dissatisfaction, lack of autonomy and social support (Bogduk, 2006; Eatough, Way, & Chang,
2.4. **Individual or genetic risk factors associated with the development of musculoskeletal disorders**

Individual characteristics are either hereditary or genetic (e.g., physical characteristics, anatomical variations, and genetic predispositions) or an outcome of external influences that may or may not be associated with the development of musculoskeletal disorders. The most obvious external influences of individual factors are: 1) developmental or acquired factors (e.g., poor posture or history of previous injury); and 2) lifestyle factors (e.g., amount of exercise, diet and smoking) (Cole & Rivilis, 2004; Wilson & Boyling, 2002, pp. 63-70).

Cole and Rivilis (2004) refer to individual risk factors as “non-work, demographic, physiological or psychological factors”. Individual or genetic risk factors are important to consider when studying musculoskeletal disorders due to their varied operation in the development, course and response to interventions of musculoskeletal disorders (Leboeuf-Yde, 2004). Individual factors tend to interact with both physical and psychosocial risk factors, therefore, being difficult to differentiate as standalone causative factors to musculoskeletal disorders and dysfunction.
2.5. Work-related physical risk factors associated with the development of musculoskeletal disorders

The work environment in the developed world over the past two decades has undergone substantial changes in terms of: sedentary nature of workplaces (Holth et al., 2008); combined exposure to awkward postures or heavy physical work and vibration (Punnett & Wegman, 2004); complexity of new technologies and human-machine interfaces, repetitive tasks or rapid work pace; and poor ergonomic design of the workplace (e.g., chair and workstation design affecting posture). These changes are all examples of physical risk factors that may contribute to the development of musculoskeletal disorders and dysfunction. Computer use has attracted a substantial volume of research as a factor known to increase the risk of musculoskeletal disorders of the upper extremity (Eatough et al., 2012; Gerr, Marcus, & Monteilh, 2004; Szeto, Straker, & O’Sullivan, 2005). Along with computer use, adopting ‘poor’ or non-neutral postures and maintaining a posture for long durations is correlated with the development of musculoskeletal disorders and dysfunction (Christie, Kumar, & Warren, 1995; Corlett, 2008; Graf et al., 1995).

In summary, there are many risk factors that contribute to the development of musculoskeletal disorders and these include psychosocial, psychological and physical risk factors. The Biopsychosocial model provides a framework in which to consider these. Posture is among the physical risk factors to the development of musculoskeletal disorders that will be explored in the next subsection.
3. POSTURE AND PAIN

There are many descriptions of what constitutes ‘good’ or ‘ideal’ posture but a unified definition has not been used by musculoskeletal researchers and therapists. Earlier work suggests that ‘good posture’ is, “the state of musculoskeletal balance that involves a minimal amount of stress and strain on the body (Kendall, McCreary, Provance, Rodgers, & Romani, 2005, p. 51; Szeto et al., 2005). ‘Ideal’ standing posture is described as, “the vertical alignment of all body segments with the line of gravity passing close to, but not through all joint axes” (Levangie & Norkin, 2011, p. 491). This suggested ideal posture is unlikely to be achieved due to being biomechanically demanding on the musculoskeletal system, especially if attempting to maintain the posture for long periods. Therefore, ‘poor posture’ or postures that are not representative of ideal posture can occur.

‘Poor posture’ has been described as “the faulty relationship of the various parts of the body which produce increased strain on the supporting structures and in which there is less efficient balance of the body over its base of support” (Kendall et al., 2005, p. 51). No standard criteria or definition has been constructed for ideal or poor posture. However, clinically some changes in posture are considered to be normal, whereas others are considered to be associated with musculoskeletal disorders.

3.1. Postural aberrations

Postural aberrations can be described as, “adaptive postural changes in response to deviations from alignment to the line of gravity” (Christie et al., 1995). Furthermore, postural aberrations may be considered as components of non-ideal posture and may result from many factors including attributes of modern lifestyle and high demands of the workplace. A limitation of the definitions of posture and postural aberrations is that the element of time is absent. A temporal perspective is vital to understand why posture and postural aberrations are difficult to clinically assess and research, as the concept of duration of exposure to aberrant posture is fundamental to the development of musculoskeletal pain and dysfunction. A posture, regardless of being
ideal or not, maintained for long periods may lead to higher risk of negative musculoskeletal outcomes such as discomfort and pain (Miedema, Douwes, & Dul, 1997).

Factors that may be associated with adverse effects on the musculoskeletal system include decreased physical activity (Holth et al., 2008), sitting for long periods (Cascioli, Heusch, & McCarthy, 2011; Gerr et al., 2004) and static, non-neutral postures (Corlett, 2008; Szeto, Straker, & Raine, 2002). Clinically, there are a range of characteristics that are considered by practitioners when evaluating the quality of posture which include: rounded-shoulders; kyphotic thoracic spine, increased lordosis of the lumbar spine (commonly termed ‘sway back’) or a flexed lumbar spine. ‘Forward head posture’ and a flexed lumbar spine are examples of postural aberrations which have received attention from researchers due to their presumed association with back pain (Dolan, Adams, & Hutton, 1988) and neck pain (Caneiro et al., 2010).

Decrease in muscle strength, endurance and extensibility of the trunk, back and lower extremity muscles are factors that are prevalent in modern society and are associated with musculoskeletal pain and dysfunction (López-Miñarro & Alacid, 2009; Nourbakhsh & Arab, 2002; Taanila et al., 2012; Ylinen et al., 2004). The factors of decreased muscle strength, endurance and extensibility can be associated with poor posture but it is unknown if there is a cause and effect relationship among these and musculoskeletal pain and dysfunction.

3.2. Controversy surrounding the relationship between posture and pain

The relationship between poor posture and musculoskeletal pain is not well established (Lederman, 2010). In a recent commentary, Lederman (2010) argues that evaluating posture, structure and biomechanics as a model (what Lederman calls the “postural-structural-biomechanical model”) in relation to musculoskeletal pain, is invalid. Lederman’s (2010) argument is based on the limited evidence of relationship between putative risk factors and musculoskeletal pain and dysfunction through review of cross-sectional studies and systematic reviews. The risk factors investigated showed limited to no association to the prevalence of musculoskeletal pain. Risk factors that were investigated included (but were not limited to): poor posture (Roffey, Wai, Bishop, Kwon, & Dagenais, 2010); non-normal spinal curves (Poussa et al., 2005); biological asymmetries (Levangie, 1999); joint range of motion (Mitchell, O’Sullivan,
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Burnett, Straker, & Smith, 2008); disc degeneration (Paassilta et al., 2001); and hamstring or psoas inflexibility (Hellsing, 1988).

Takala (2010) provides rebuttal to Lederman’s (2010) commentary in regard to the relationship between posture and pain. Takala (2010) suggests that, in epidemiological studies, “The lack of evidence of an effect size is not evidence of the lack of an effect”. Therefore, no statistically significant results within correlation studies and systemic reviews investigating risk factors to musculoskeletal disorders, does not mean that the association of risk factors to musculoskeletal pain does not exist, as risk factors may still be clinically informative. Some studies (Roffey et al., 2010; Wai, Roffey, Bishop, Kwon, & Dagenais, 2010) have attempted to investigate independent causative association of risk factors, but given the multicausal aetiology of musculoskeletal pain this may not be achievable.

The type of study design determines the extent to which causal association can be made, and the investigation of causation requires experimental designs that include controls. Identifying variables is possible, however, controlling for these variables over sufficient periods of time to allow the onset of musculoskeletal pain is not viable. In response to this challenge, epidemiological designs are used to investigate the strength of association between variables but this does not constitute identification of cause and effect.

Despite doubts of the validity of risk factors (e.g., poor posture) causing musculoskeletal pain, the fact remains that manual and physical therapists use the postural-structural-biomechanical model in routine clinical practice for informing their clinical diagnosis, treatment and management of patients. Postural aberrations may affect different individuals to varied extents and in a number of ways such as musculoskeletal pain, muscle stiffness and weakness, musculoskeletal and physiological compensations. Therefore, when considering individuals, and without concrete evidence of the association of risk factors to musculoskeletal pain, musculoskeletal practitioners often choose to implement the postural-structural-biomechanical model in clinical practice. Postural aberrations of ‘forward head posture’, lumbar spine postural aberrations and reduced muscle endurance, strength and flexibility are still clinically managed due to their presumed (but not well demonstrated) association to musculoskeletal disorders.
Postural aberrations and reduced muscle endurance, strength and flexibility in relation to musculoskeletal pain and dysfunction will be discussed hence forth.

3.3. ‘Forward head posture’

‘Forward head posture’ is a characteristic posture recognised by practitioners when the head is observed in an anterior position in relation to the line passing through the body’s centre of gravity (Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992). It is one of the common types of poor head-neck posture seen in patients with neck disorders (Silva, Punt, & Johnson, 2010; Szeto et al., 2002; Yip, Chiu, & Poon, 2008). It is suggested that office workers frequently assume static neck and shoulder posture which increases joint and soft tissue loading and subsequently increases the risk for developing pain and upper limb musculoskeletal disorders (Szeto et al., 2002).

A study by Yip et al. (2008) was one of the first studies to positively correlate forward head posture, neck pain and disability. This study demonstrated that participants with small craniovertebral angles had greater forward head posture. The craniovertebral angle is characterised by a horizontal line from the spinous process of the seventh cervical vertebra in a lateral view intersected by a line to the tragus of the ear. The key finding reported by Yip et al. (2008) was that the greater the forward head posture, the greater the self-reported neck disability. This study was a cross-sectional correlation study with n=62 participants with neck pain and n=52 without neck pain (controls). Yip et al. (2008) report that the craniovertebral angle of the neck pain group (mean ± SD = 49.93 ± 6.08°) was significantly smaller than in the control group (mean ± SD = 55.02 ± 2.86°). The reliability of measurement of the craniovertebral angle was reported to be consistent (ICC = 0.98). However, the use of intra-class correlation coefficients for the reliability of measuring craniovertebral angles may have had an effect of inflating the correlation due to high assessor recall bias, as the assessor measured three craniovertebral angle measurements with a short interval between repeated measures.

The alignment described by Kendall et al. (2005) for ideal posture describes the head and neck being in a well balanced position with minimal muscular effort, but this does not occur in forward head posture. A theory proposed by Janda (2002) suggests muscles often respond to pain and dysfunction by either weakening or tightening causing muscle imbalances. Janda (2002)
proposed a classification system for muscle imbalances whereby muscles that tend to tighten usually have a ‘postural’ function and are involved in static tasks (standing and sitting), whereas the dynamic or ‘phasic’ muscles tend to weaken, become inhibited and are involved in dynamic movement (Key, 2010; Liebenson, 2007, p. 37).

Forward head posture has been characterised to have muscle imbalances such as tightness of the postural muscles such as the upper trapezius, pectoralis major, and levator scapulae. Weakness is thought to occur in the dynamic muscles such as the rhomboids, serratus anterior, middle and lower trapezius, deep neck flexors, and the scalene muscles. This neck muscle imbalance is known as the ‘Upper Crossed Syndrome’ by some authors (Key, 2010; Liebenson, 2007). Loss of strength (force) of cervical musculature of the head-neck complex has been associated with neck pain (Dvir & Prushansky, 2008; Falla, Jull, Hodges, & Vicenzino, 2006), but the extent to which muscle imbalances have been described by Janda (2002) has not been thoroughly established through empirical research. It has been demonstrated that the sternocleidomastoid and anterior scalene muscles have greater fatigability in neck pain subjects than controls (Falla, Rainoldi, Merletti, & Jull, 2003). However, no correlation was found between duration of chronic neck pain and fatigue of the sternocleidomastoid and anterior scalene muscles (Falla, Rainoldi, Jull, Stavrou, & Tsao, 2004).

Along with muscle imbalances, there are many clinical signs and symptoms that have been associated with forward head posture, examples include: decreased range of neck motion; muscle stiffness or pain; non-normal flexion-relaxation response in cervical erector spinae (Burnett et al., 2009); degenerative changes in the spine (McAviney, Schulz, Bock, Harrison, & Holland, 2005); headaches; shoulder pain (Braun & Amundson, 1989); and temporomandibular joint disorders (de Farias Neto et al., 2010). Although evidence exists for the association of pain and dysfunction related to posture, causative links have not been definitively demonstrated (Ylinen et al., 2004).

3.4. ‘Postural lower back pain’

To date there is limited good quality evidence as to whether lumbar spine posture plays a substantial role in the development or maintenance of lower back pain (O’Sullivan, Mitchell, Bulich, Waller, & Holte, 2006), nevertheless, it appears to be widely accepted in the manual and
manipulative therapy community that poor posture may play a role in the development of lower back pain hence the use of the term ‘postural lower back pain’ amongst practitioners (During, Goudfrooij, Keessen, Beeker, & Crowe, 1985). Postural related risk factors correlated with back pain include: flexion of the spine when sitting (Adams & Hutton, 1985); bending or stooping postures (Dolan & Adams, 1998); non-neutral postures (Splittstoesser et al., 2007); and excessive extension of the lumbar spine when standing (Scannell & McGill, 2003). Postural lower back pain has been associated with many postural related risk factors, but have limited to no established causal relationship (Lederman, 2010).

The lack of research evidence in support of poor posture being associated with low back pain may be at least partially explained by the multifactorial nature of low back pain (Nourbakhsh & Arab, 2002). Back pain is a heterogeneous clinical complaint (Bogduk, 2006; Burton, 2005) and recent research has demonstrated that distinct sub-groups of back pain exist (Kamper et al., 2010). Different sub-groups may have different mechanisms of causation and may respond to different forms of intervention. Failure to account for subgroups when investigating the relationship between posture and low back pain may lead to errors in drawing conclusions if the study samples are not well defined or include different sub-groups. Research investigating the relationship between back pain and posture is further threatened by the absence of objective criteria that define normal or abnormal posture. Even though there is inconsistent evidence, risk factors that are associated with lower back pain must be taken into consideration for clinical management of lower back pain.

Postural aberrations that are observed by clinicians and are associated with back pain include: increased lordosis also known as ‘extended’ or ‘swayback’ (Vergara & Page, 2002); flexion of the lumbar spine is also known as ‘slouched’ or ‘slumped’ posture (Christie et al., 1995). Sitting is considered as an important factor in the aetiology of back pain, but with no independent causation demonstrated (Womersley & May, 2006). Further to this, some researchers suggest that back pain while sitting is more likely to occur in combination with other factors such as restricted and static postures held for long periods of time (Corlett, 2008; Graf et al., 1995; van Dieën, Jansen, & Housheer, 1997). Research has demonstrated that sitting posture with a flexed lumbar spine (posteriorly rotated pelvis) adds greater stress on lower back structures and soft tissue (Bridger, Orkin, & Henneberg, 1992; Corlett, 2008; Harkness et al., 2005; Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999; Womersley & May, 2006).
Static postures sustained over prolonged periods have been suggested to be detrimental to the musculoskeletal system due to a proposed increase in intramuscular load and increase in muscular fatigue (Dupeyron, Lecocq, Vautravers, Péliissier, & Perrey, 2009). Therefore, some physical therapists and ergonomists claim that regular movement is the key for combating back pain associated with sedentary work. Therefore, in an attempt to reduce musculoskeletal disorders associated with prolonged static positioning, the development of ergonomic tools and strategies such as ‘dynamic chairs’ (Ellegast et al., 2012) and ‘standing desks’ (Gilson, Suppini, Ryde, Brown, & Brown, 2012) have started to emerge in ergonomic practice.

‘Dynamic chairs’ are meant to reduce fatigue, creep and postural inflexibility as some movement are undertaken routinely throughout the day to activate muscles while in a seated position (Ellegast et al., 2012). ‘Standing desks’ are not a new concept and were popular in the 18th and 19th centuries in homes and offices (Gilson et al., 2012; Schofield, Kilding, Freese, Alison, & White, 2009). The use of standing desks is a direct attempt to reduce the time spent with flexed hips and may also encourage a less sedentary position because standing has greater energy demand than sitting (Speck & Schmitz, 2011).

Recent preliminary research by Gilson et al. (2012) investigated the use of standing desks in a sample of office workers but found that sedentary work time was affected only minimally. This finding may be inaccurate as the change in behaviour from sitting to standing was not accurately measured. The sedentary time monitoring device (accelerometer) used in this study measures ground reaction forces in different planes (Ramirez, 2011) and there may be errors in differentiating standing from sitting. For example, if standing still with minimal movement, the data may be misinterpreted as sedentary time. Therefore, further research into more sensitive objective means of assessing sedentary time is required to better inform the conclusions of standing desk research.

3.5. Muscle deconditioning

Attributes of modern society, such as high levels of sedentary activities and prolonged occupational sitting postures may have negative health implications on the musculoskeletal system. Inactivity has been linked to a decrease in muscle strength and endurance (Bousema, Verbunt, Seelen, Vlaeyen, & André Knottnerus, 2007). Muscle strength has been defined as the
maximal force produced by a given muscle, and muscle endurance as the extent to which a given sub-maximal force can be sustained (Falla et al., 2006). The loss of muscle strength and endurance is often termed ‘muscle deconditioning’ (Verbunt et al., 2003) and represents a non-desirable physiological state.

It has been shown by many authors that people with lower back pain often have reduced back muscle endurance and strength (Elfving, Dedering, & Németh, 2003; Mulhearn & George, 1999; O’Sullivan et al., 2002; O’Sullivan et al., 2006; Troup & Videman, 1989). Reduced back muscle strength and endurance can be a consequence of many factors including inactivity (Bousema et al., 2007), occupational sitting postures (Edmondston et al., 2008) as well as deconditioning associated with fear-avoidance of movement. A recent study investigating the relationship between psychological factors and the performance of a back muscle endurance test in back pain patients (Mannion, O’Riordan, Dvorak, & Masharawi, 2011) highlights the role of psychological factors such as fear-avoidance in the influence on outcomes of back muscle endurance tests. These study findings raise interesting questions about the nature of the relationship between back pain and muscle endurance test outcomes. Therefore, it is possible that muscle endurance test outcomes are not representative of true muscle function.

Reduced back muscle endurance and strength is associated with decreased postural awareness and muscle function which can lead to an increased lordosis or a flexed lumbar posture in lower back pain patients (O’Sullivan et al., 2006). It is proposed that standing with an increased lordosis and sitting in a hyper-flexed posture may decondition lumbar stabilising muscles and increase load on passive structures of the spine thereby increasing the risk of injury (Cholewicki & McGill, 1996).

Lower muscle activity or reduced abdominal wall strength and stability are often claimed by clinicians as being related to back pain (Silfies, Squillante, Maurer, Westcott, & Karduna, 2005; Taanila et al., 2012). However, conflicting evidence for these claims exist and the topic of muscle function and back pain is contentious (Lederman, 2010). For example, in a sample of elite golfers abdominal muscle activity and muscle fatigue characteristics were similar in both asymptomatic and symptomatic (chronic low back pain) participants after repetitive golf swings (Horton, Lindsay, & MacIntosh, 2001). Despite clear evidence of association, it remains unclear whether impaired muscle function in terms of strength, endurance and motor control are a cause or an effect of lower back pain.
3.6. *Muscle inflexibility*

It is clinically believed that frequent and prolonged sitting is associated with postural adaptations such as muscle inflexibility and stiffness (Cascioli et al., 2011). It has been clinically observed that muscle inflexibility of the hamstring muscles and the hip flexors occur commonly in people complaining of musculoskeletal symptoms such as back pain (Hellings, 1988). There is research data to show hamstring muscle inflexibility in individuals with lower back pain (Alston, Carlson, Feldman, Grimm, & Gerontinos, 1966; Biering-Sørensen, 1984; Hultman, Saraste, & Ohlsen, 1992; Mellin, 1988; Norris & Matthews, 2006). Possible reasons for the association of back pain to hamstring and hip flexor inflexibility include: the posterior pelvic rotation of the habitual seated posture sustained for long durations of time, physical inactivity, decrease in back muscle strength and endurance possibly causing hamstring and hip flexor muscles to be overactive (Spernoga, Uhl, Arnold, & Gansneder, 2001).

Although many justifications can be made of the relationship between muscle inflexibility and lower back pain, this relationship has not been substantiated through extensive or high quality research. Therefore, inconsistent evidence of independent causality and even association of muscle inflexibility and back pain makes investigation and assessment difficult for musculoskeletal researchers and therapists (Hellings, 1988; Nourbakhsh & Arab, 2002; Renkawitz, Boluki, & Grifka, 2006; Tafazzoli & Lamontagne, 1996).

In summary, postural aberrations and muscle strength, endurance and extensibility are correlated with musculoskeletal pain, but cause or effect relationships have not been definitively established. Although the nature of cause and effect relationships between posture and musculoskeletal pain remain unclear, physical and musculoskeletal therapists use the assessment of posture to guide diagnosis and subsequent management in clinical settings. Assessment of posture is explained in the next sub-section.
4. ASSESSMENT OF POSTURE

For convenience, it is common to consider posture in a static or dynamic context. It has been suggested that, “an understanding of static posture forms the basis for understanding dynamic posture and that posture and movement are interrelated” (Levangie & Norkin, 2011, p. 484). Consistent with the interrelation of posture and movement, osteopaths and other physical therapists employ a musculoskeletal physical examination that includes the observation of the quality of both posture and movement (Spring, Gibbons, & Tehan, 2001; Ward et al., 2003).

Observation or visual methods are the most prevalent form of postural evaluation among musculoskeletal therapists, which include tools of photographic (Dunk, Lalonde, & Callaghan, 2005), video (Neumann et al., 2001), or radiographic imaging (Grimmer-Somers, Milanese, & Louw, 2008). Observation methods that rely on practitioner judgement of observation are routinely used due to being easily accessible, time efficient and inexpensive. However, intra-examiner reliability of posture analysis is low (Dunk et al., 2005) due to high levels of subjectivity associated with the assessment of posture.

4.1. Typical musculoskeletal physical examination

In a typical musculoskeletal physical examination (also known as neuromuscular assessment) the general process is to evaluate various anatomical structures following a systematic approach. Posture is often used as a key indicator for initial evaluation of dysfunction making postural assessment a fundamental clinical skill in all form of physical therapy (Seidel, Ball, Dains, & Benedict, 2006, p. 705). Through a clinical reasoning process the use of postural observation in conjunction with orthopaedic testing informs diagnosis, treatment and subsequent management (Seidel et al., 2006).

Clinically, posture assessment provides information about structure and function of the musculoskeletal system, allowing evaluation of the effects of treatment. Examples of postural components that are examined include: decreased range of motion or asymmetry of spinal curves and bony landmarks (Kendall et al., 2005, p. 53), but the relationship between postural asymmetry and pain lacks convincing evidence. For example, musculoskeletal therapists assess
pelvic asymmetry, but the common association of pelvic asymmetry to back pain has been demonstrated to not have any meaningful association (Levangie, 1999).

4.2. **Orthopaedic neuromuscular assessment**

Orthopaedic neuromuscular testing examines single structures, joints and tissues of the musculoskeletal system and is used by many health professionals including osteopaths and physical therapists to assist diagnosis, treatment and management (Conable & Rosner, 2011). A typical orthopaedic neuromuscular examination involves assessment of joint ranges in single planes of motion, evaluation of muscle length and tension, and palpation of soft tissue and then relating an isolated structure to pain or dysfunction. The orthopaedic approach of diagnosis can be referred to as the identification of dysfunction or pain linked to specific anatomical structure. The orthopaedic approach of specific tissue diagnosis, despite having diagnostic criteria, can at times be confusing due to the complexity of real-life presentations. Ambiguous characteristics may be associated with the findings of clinical tests due to limitations in utility (reliability and validity) and variations of inter-practitioner methodology of performing the clinical tests (Dixon & Keating, 2000).

Physical and exercise therapists use a musculoskeletal model of assessment called the ‘Regional Interdependence Model’ that considers assessment of body regions above and below the painful and dysfunctional region (Wainner, Whitman, Cleland, & Flynn, 2007). This model is based on evidence that suggests there may be dysfunction in remote regions from the painful site (Wainner et al., 2007). Therefore, uncertainty may exist with the orthopaedic approach of specific tissue diagnosis, as relating tissue causing symptoms to a specific joint or muscle, may affect the validity of the diagnosis as dysfunction may be present in remote areas.

4.3. **Global approach of musculoskeletal assessment**

A ‘global’ approach of assessing the musculoskeletal system is described in major osteopathic (Dummer, 1999; Greenman, 1996) and exercise therapy texts (Hoogenboom, Voight, & Cook, 2012; Wainner et al., 2007) as an assessment that includes more than one body region and does
not isolate single named structures. The ‘global’ approach includes methods of ‘screening’ or ‘scanning’ posture as well as movements that are either active (patient moves themselves) or passive (practitioner moves patient) (Dummer, 1999; Greenman, 1996; Seffinger, Hruby, & 2007). It has been suggested by many authors (Key, Clift, Condie, & Harley, 2008; Mitchell, Bressel, McNair, & Bressel, 2008; Myers, 2009; Stecco et al., 2009) that the myofascial system is an inter-dependent and continuous system. For example, the assessment of the ‘posterior muscular chain’ considers the inter-dependence of posterior leg and back muscles (Szlezak, Georgilopoulos, Bullock-Saxton, & Steele, 2011).

The global approach of physical assessment is suggested to be a comprehensive screening and diagnostic method (Wainner et al., 2007). The Regional Interdependence Model is an example of a global approach of assessment. It is believed that dysfunction in one region can affect remote regions, which is an idea supported by case studies where hip function influences knee dysfunction (Reiman, Bolgla, & Lorenz, 2009); and lower back pain and sacroiliac joint pain is related to dysfunction in the hip, knee and foot (Cibulka, 1999; Wainner et al., 2007).

In summary, posture assessment is either performed with dynamic or static postures and movements, providing a musculoskeletal therapist with information of musculoskeletal structure and function. In contrast to an orthopaedic approach of specific tissue assessment and diagnosis, a global approach of musculoskeletal assessment offers an integrated approach of components of the musculoskeletal system. Screening and scanning of the musculoskeletal system is discussed in the next subsection.
5. SCREENING AND SCANNING

Screening examinations of the musculoskeletal system are commonly used as clinical screening assessment tools by musculoskeletal practitioners. In public health and general medicine ‘screening’ has been described as, “making an early diagnosis of pre-symptomatic disease among well individuals in the general public” (Sackett, Straus, Richardson, Rosenberg, & Haynes, 2000). In musculoskeletal medicine the ‘screening’ examination answers the question, “Is there a problem within the musculoskeletal system that deserves additional evaluation?” (Greenman, 1996, p. 18).

Physical therapy and sports medicine practitioners suggest that screening is a prelude to more detailed assessment of any kind, including range of motion tests and/or flexibility tests. For example, in the evaluation of movement based activities the role of screening tools is to screen the movement capability (quality and extent of movement) of the individual before more complex movement tasks are performed (Hoogenboom et al., 2012). This method of evaluation helps to distinguish an individual’s normal movement from dysfunctional movement and is commonly used in the context of pre-participation for sport (Cook, Burton, & Hoogenboom, 2006) and rehabilitative evaluation of risk and prevention of injury (Hoogenboom et al., 2012).

5.1. Benefits of screening approaches to assess the musculoskeletal system

There are many reasons why practitioners may choose to use screening approaches to assess their patients. The characteristics of screening assessments in a musculoskeletal context includes: usefulness, objective measurement, time efficiency, accessibility and cost-effectiveness:

- Useful: Screening is used to identify movement patterns that produce pain within normal ranges of motion, and identify non-painful but limited movement patterns that are likely to demonstrate higher potential risk of injury with exercise and activity. Furthermore, screening informs a practitioner about exercises or activities that should
be avoided and may also be useful in identifying the most appropriate pathway for intervention (Hoogenboom et al., 2012).

- **Objective measurement:** most developed screening tools have grading criteria and therefore assessment of movement patterns or treatment effects can be objectively evaluated (Bokarius, 2010; Paternostro-Sluga, Preisinger, Uher, Resch, & Ernst, 1995).

- **Time efficient:** postures and movements that are assessed are mostly multi-articular, therefore the assessment provides a global approach compared to single muscle and joint testing of orthopaedic diagnosis.

- **Accessible and cost-effective:** screening tools should be easily accessible during a standard consultation and are widely available. Therefore, screening methods do not rely on higher levels of technological investment as most musculoskeletal practitioners rely on visual assessment methods to assess quality of movement.

### 5.2. Screening and scanning of the musculoskeletal system in osteopathy

Screening in osteopathy of the musculoskeletal system is used as a preliminary assessment process to identify musculoskeletal dysfunction, but not to characterise dysfunction. According to Greenman (1996) the ‘screening’ examination answers the question, “Is there a problem within the musculoskeletal system that deserves additional evaluation?” and proposes ‘scanning’ as the follow-on to screening which answers the question, “What parts of the region, are significantly dysfunctional?” The purpose of screening posture and movement patterns is for the assessment of competency, quality, symmetry, stability and strength of the musculoskeletal system and identification of regions that may be dysfunctional. Appropriate intervention is then predicated on an appropriate screening process.

The two most prominent screening approaches used in osteopathy are: 1) Greenman’s 10-Step Screening (Greenman, 1996); and 2) Littlejohn’s screening approach (Dummer, 1999). Greenman (1996) implements ‘scanning, screening and segmentally defining’ through a ‘10-step’ evaluation protocol of the musculoskeletal system. The ‘10-step’ screening evaluation consists of static postures and dynamic movements, where information can be gained about the mobility and the curvature of the spine, symmetry of structure, and quality of movement. Dysfunctional areas are identified with further evaluation through scanning then passive examination of
segmentally defining. Orthopaedic tests for specific structure and tissue diagnosis may then be used to assess a dysfunctional region for a diagnosis to be made (Greenman, 1996, p. 18).

Littlejohn’s model of body mechanics is taught as fundamental knowledge in the osteopathic context of examination. In this model the body is divided into three regions (which Littlejohn terms ‘unities’), each region having important structural bases of support in which most forces of the region concentrate. The regions were most force concentrates include structures that provide the most movement and is termed by Littlejohn as ‘pivotal regions’ of movement. The three regions are inter-related with ‘line of forces’ and collectively known as ‘polygon of forces’. This can be explained as anti-gravity lines that have forces acting on the spine anteriorly and posteriorly. In a clinical examination, movements are performed as a screen to identify the regions that are significantly dysfunctional but, just like Greenman’s (1996) screen, the screen does not categorise the dysfunction (Dummer, 1999, pp. 177-187).

5.3. Limitations of Greenman’s and Littlejohn’s musculoskeletal screening approaches

Greenman’s and Littlejohn’s musculoskeletal systematic screening approaches provide tools for the collection of information that can be used to consider the relationship and integration of all body parts to function. However, due to the many steps needed to complete both screening approaches more often than not, attention is focused on the dysfunctional region which negates a global evaluation and treatment of the whole kinetic chain (Nicholas, Grossman, & Hershman, 1977). Furthermore, objective quantification (e.g., scoring of quality by assigning a number) is not used in both these screening approaches. Subjective and qualitative evaluation of posture and movement without grading criteria may prevent reliable tracking of patient progress between sessions.

In summary, screening and scanning of the musculoskeletal system is used by osteopaths and physical therapists for many reasons, but particularly important is the potential to identify an individual’s dysfunction from normal patterns of movement or posture. A discussion of ‘functional movement’ and ‘functional movement screening’ follows in the next subsection.
6. FUNCTIONAL MOVEMENT SCREENING

‘Functional movement’ can be defined as, “the range of purposeful movements associated with common task related activities” (Durward, Baer, & Rowe, 1999). Screening of functional movement and evaluation of whole body function can be termed ‘functional movement screening’. Screening tools and whole body evaluation methods of function have been used for at least the past decade in physical and exercise therapy and are typically used to evaluate movement patterns of an athlete or an individual (Lombardo & Badolato, 2001; Miller & Callister, 2009).

The aim of evaluating whole body quality of functional movement is to simulate movements of daily living which inherently integrates multiple muscles and joints. Squatting (Kritz, Cronin, & Hume, 2009), lunging (Cook et al., 2006) and forward bending of the trunk (Liebenson & Yeomans, 1997) are examples of movements that are commonly used and are considered functional. The multi-articular nature of functional movements allow practitioners to assess the musculoskeletal system globally and in a time efficient manner, compared to isolated orthopaedic testing of isolated joints or tissue. The apparent quality of movement is considered important when assessing functional movement (Cates & Cavanagh, 2009).

In critique of screening dynamic movement, some authors propose that screening complex dynamic movement patterns requires a high degree of skill and is not reliable due to the sole use of practitioner clinical judgement and observation (Weir et al., 2010). Although, complexity of assessing movement is apparent, practitioners obtain high reliability in measuring functional movement from screening tools such as the ‘Functional Movement Screen’ (Cook et al., 2006; Minick et al., 2010) as well as functional performance tests such as hop tests (Bolgla & Keskula, 1997). The high reliability observed with these screening tools may be due, at least in part, to well refined and simple grading criteria being published.

6.1. Developed functional movement screens and research methods

There are many screening assessments of movement quality and injury risk that have been developed. Examples of developed functional screening approaches include: Pre-participation
Collectively, movement-based screens are well developed due to ongoing research over many years, along with routine clinical utilisation by many physical and exercise therapists. Functional movement screens have been developed through many phases of research and these are outlined in Figure 1. Figure 1 is a conceptualisation of the pathway of screening tool development. For any screening tool to emerge, new or un-established ideas are explored from theories and clinical practice, which is considered to be the Developmental Phase of research (Figure 1A). To investigate the ideas or concepts that form the basis of the screening tool, reliability or validity research would need to be conducted and trialled in clinic, numerous times before the ideas and concepts become a Preliminary Model or preliminary screening tool (Figure 1B). Further research into reliability of the tool allows dissemination of the developed screening tool and therefore becomes a published Practical Model (Figure 1C). Through iterative processes the screening tool is used in practice and researched simultaneously with ongoing development in clinical use and formal research (Figure 1D).

The main movement based screens that have been widely used due to their established reliability are the Functional Movement Screen (Cook et al., 2006; Hoogenboom et al., 2012) and Star Excursion Balance Test (Plisky et al., 2006). The summary of the phases of research development highlights at what stage the Functional Movement Screen (Cook et al., 2006) has been developed (Figure 1D).
6.2. Types of research needed to develop screening tools

Many types of research can be used to develop screening tools and the main types are outlined in Figure 2 which is adapted from Trochim (2006). Reliability research (consistency of measures) and validity research (how correct or true the measure is) are typically the initial investigations made in the development of a screening tool (Trochim, 2006) and can be implemented at any stage during development of the tool. Effectiveness research and diagnostic test parameters can be investigated as follow-on to reliability and validity research. Ultimately, a screening tool should be reliable and valid for effective clinical utility.

It is important to establish reliability of clinical screening tools so that comparisons between measures or results can be validly compared between patient consultations. Furthermore, consideration of investigation of test-retest reliability of a component being measured (e.g., movement or posture) is important. For example, variability of posture within and between sessions is important to verify posture reliability and changes due to an introduced intervention can be clearly identified and calculated. Measurements arising from any screening tool can be reliable (consistent) between consultations, but may not be valid (closeness to the true measure). Validity is an important aspect of clinical research composed of both internal and external validity, and analyses the credibility and accuracy of what the screening tool or criteria is intended to measure or assess (George, Batterham, & Sullivan, 2003).

**FIGURE 2 - TYPES OF RESEARCH**
6.3. **The Functional Movement Screen**

For explanation purposes, one of the most developed movement-based screens, the Functional Movement Screen (Cook et al., 2006), will be discussed as an example of a well defined global and objective approach to screening movement.

The Functional Movement Screen was developed by Cook et al. (2006) to evaluate the quality of movement patterns of athletes and individuals through seven fundamental movement tests which include the Deep Squat, In-line Lunge, Hurdle-Step, Active Straight Leg Raise, Trunk Stability Push Up, Shoulder Mobility and Rotary Stability. Each of these fundamental movement tests are designed to implement fundamental movement patterns of physical function such as flexion-extension, side-bending, twisting or rotation and push-pull patterns. These fundamental movement patterns are integrated in daily activities but to different extents and require varied levels of strength, stability and mobility of body segments.

It has been suggested that individuals who perform at high functional levels during normal activities may be unable to perform these simple functional movements if mobility or stability is not present (Kiesel, Plisky, & Voight, 2007). Therefore, despite the simplicity of the functional movements within the Functional Movement Screen it has been observed that the “movements provide sufficient challenge to identify the presence of strength deficits, asymmetries between left and right side of the body and poor motor control” (Hoogenboom et al., 2012).

6.4. **Scoring of the Functional Movement Screen**

The Functional Movement Screen is widely used (particularly in North America) as an injury prediction tool and for rehabilitation to track performance (Hoogenboom et al., 2012). Grading criteria has been well developed and is scored using a simple scoring system whereby each movement pattern is scored with four possibilities on a 0-3 ordinal scale. A score of 0 is assigned if at any time pain is experienced anywhere in the body. A score of 1 is given if the person is unable to complete the movement pattern or is unable to assume the position to perform the movement. The score 2 is given if the person is able to complete the movement but must compensate in some way to perform the fundamental movement. The score of 3 is given if the person performs the movement correctly without any sign of compensation.
The Functional Movement Screen has been widely used in athletic populations (Kiesel et al., 2007). An athlete that experiences pain during the performance of a movement, a score of 0 would be given despite the ability to complete the movement. This approach is recommended as the presence of pain can be a biomechanical sign of musculoskeletal injury or compensation that may not be apparent during daily activities and sport. The presence of movement compensation is considered by Cook et al. (2006) as “a factor that may increase the risk of musculoskeletal injury, or in the case of a known injury, be a limiting factor in rehabilitation and return to normal function.” If an athlete has no pain but displays dysfunctional movement, corrective exercise therapy would be used to address dysfunction, preventing compensatory movements and ultimately reducing risk of future musculoskeletal dysfunction or injury (Hoogenboom et al., 2012).

6.5. **Limitations of the Functional Movement Screen**

The Functional Movement Screen has not been thoroughly investigated on inactive, non-athletic populations although the Functional Movement Screen is intended to be used on “healthy, active individuals as well as healthy, inactive individuals who would like to increase their physical fitness” (Hoogenboom et al., 2012). The scoring of inactive individuals may prove difficult due to the probability of pain and dysfunctional movement patterns being more prevalent compared to athletes, although, even highly skilled athletes have been suggested to have pain and show fundamental imperfections in their movement (Hoogenboom et al., 2012). The effect of an individual’s pain level on grading, within the Functional Movement Screen is exemplified when an individual has slight pain but may be able to carry out the movement pattern. For this example the score would be 0 because of the pain factor, as opposed to a score of 1, 2 or 3 if pain was not present.

For the Functional Movement Screen to be utilised in populations other than athletes, review of the scoring system may be needed or other screens developed to simulate activities of daily living, for grading of optimum function specific to certain populations. For example, quality assessment of static posture used in everyday activities (e.g., sitting) may be suitable for inactive, non-athletic individuals who are involved in prolonged sitting.
In summary, the concept of a whole body function assessment using functional movement is used widely. Screening tools that are well established integrate evaluation of the quality of fundamental movement and employs a well refined objective grading system. The Functional Movement screen is well established for use in an athletic population. Static posture screening in the form of assessing floor sitting postures for the non-athletic populations is discussed in the final subsection of this review, including rationale for research on static floor sitting postures.
7. **STATIC POSTURE SCREENING**

Movement based screens may be more applicable to physically active individuals than to inactive individuals. It would be reasonable to assess athletes with movement based screens as movement is part of their lifestyle. However, the movement based screens may be less relevant to inactive individuals who may rarely perform whole body function movements but rather spend considerable time in static postures. Sitting for instance, may be the most commonly adopted posture of the inactive during work and leisure. The most desirable solution for this disparity of level of physical activity between athletes and sedentary individuals may be to encourage movement and physical activity among sedentary individuals, but this is not easily achieved and in the short term there is a need for an assessment that may reflect the extent to which an individual is able to adapt to the demands of static seated postures.

Assessment of static posture such as seated posture is routinely used by physical and exercise therapists, but the static postures used do not utilise a whole body approach of assessment in a functional manner. Screening or assessing the squat as a functional movement or posture is common among physical therapists (Liebenson, 2003), but there are other postures that are considered functional, and can be used as a screening assessment similar to the squat. Beach (2010), a New Zealand osteopath and author suggests floor sitting postures as a means of assessing dysfunction in the musculoskeletal system. Floor sitting postures are functional postures which include squatting, kneeling or cross-legged sitting.

7.1. **Floor sitting postures**

Beach has described a clinical physical examination process that involves the assessment of seven main static floor sitting postures with several variations. The postures are: the Squat; Kneel; Long Sit or Straight Leg Sit; Cross-legged-Sit; Drinking Posture (fetus position); Cowboy Posture (kneeling with one leg up) and the Side Saddle Posture (both heels to one side). The physical examination process described by Beach includes the assessment of both static and dynamic floor sitting postures. Assessing these postures has been proposed as a functional approach to assessing the musculoskeletal system (Beach, 2010). Beach suggests that sitting in
these floor sitting postures interchangeably, challenges the torso and lower extremity muscles and joints to near full range of motion and “resets muscles length-tension relationships due to passive stretching of muscles”. Further to the dynamic aspect of the postures, Beach suggests standing up from the floor sitting postures as form of exercise that challenges the musculoskeletal system, and can be used to teach individuals of motor control for daily living. Beach’s promotion of using the transition between postures as exercise is similar to the ideas of Liebenson and Shaughness (2011) who advocate using the ‘Turkish Get-Up’ as a functional movement that starts from lying on the floor to the progression of integrating functional movements such as the lunge, side-plank and the bridge to a standing position, with the additional use of a hand held weight such as a dumb-bell (Liebenson & Shaughness, 2011).

Many people use their bodies in daily living in the range of motion and to the extent the floor sitting postures challenge the musculoskeletal system, but it is mostly individuals in developing countries (e.g., African and Asian countries) that routinely use floor sitting postures (Bridger, 1991; Gurr, Straker, & Moore, 1998; Watanabe, Kobara, Ishida, & Eguchi, 2010). Beach suggests that attributes of the modern lifestyle such as inactivity, adapting to sitting on a chair, and poor diet effects on the body such as being overweight, have contributed to the commonly reported discomfort and high perceived effort required by all (athletic or non-athletic) individuals required to sit on the floor. This notion has not been substantiated through research as no normative data is available for floor sitting postures. Floor sitting postures may sufficiently challenge stability and mobility of the musculoskeletal system, and may possibly be beneficial as a screening approach.

7.2. Limitations of floor sitting postures

Assessing floor sitting postures in modern individuals may not be easily adopted as the postures are not customary, even though as toddlers these floor sitting postures are naturally adopted. Beach (2010) emphasises safety when performing the postures as well as moving from one posture to the other to prevent discomfort or pain. Most of the floor sitting postures involve increased angles of flexion of the lower back, knees and ankles. Many studies (Dionisio, Almeida, Duarte, & Hirata, 2008; Hefzy, Kelly, & Cooke, 1998; Kapoor, Mishra, Dewangan, & Mody, 2008; Koshino et al., 2002; Zelle, Barink, Loeffen, De Waal Malefijt, & Verdonschot, 2007) have
demonstrated increased compressive and shearing load within the knee joints in angles of increased flexion. In the studies that investigated kneeling (Hefzy et al., 1998) and squatting (Dionisio et al., 2008) the near full range of flexion in these postures were sustained for long durations with little movement which may increase the compressive loading effects on the joint. The study of Dionisio et al. (2008) investigated the squat as an exercise with external load, but floor sitting postures can be assessed as a screen without external load.

Thigh-calf contact is suggested to reduce muscle forces in the knee during high knee flexion such as kneeling or squatting (Zelle et al., 2007). Achieving thigh-calf contact may explain why some individuals can maintain kneeling and squatting in a relaxed manner, while others that may not achieve sufficient thigh-calf contact or knee flexion may experience discomfort and increased demand on the musculoskeletal system to maintain the posture. For a musculoskeletal screening tool the characteristic of joints being utilised to their end range may be beneficial as the musculoskeletal system may be sufficiently challenged to then identify musculoskeletal dysfunction.

7.3. Proposed Research

The clinical value of floor sitting postures has not been researched and hence there is a need for basic investigation of these postures in a clinical setting. Objective measurement of functional screening methods for the physically inactive or non-athletic population is lacking and therefore static screening of floor sitting postures may be a potentially viable assessment method. Therefore, with the lack of research and a systematic approach to grade floor sitting postures, research is needed. The collective group of movement based screens have been well established through stages of research (Figure 1). The Functional Movement Screen is being verified for its validity and reliability through extensive research (Figure 1D), on the contrary, floor sitting postures have only begun exploration of concepts and ideas and are at a preliminary stage of investigation (Figure 1 B).
Prior to researching whether floor sitting postures could be useful in screening or even as possible clinical outcome measures consistency in performing the floor sitting postures (reliability of the postures) needs to be established, as well as a systematic method to grade these postures.

The Aims of the research reported in Section II of this thesis are:

1) the development of objective grading criteria for selected postures; and

2) to investigate single rater test-retest reliability of the floor sitting postures
CONCLUSION

The historical transition from the active lifestyle of the hunter-gatherer to a largely inactive modern lifestyle may be an important factor associated with the development of postural aberrations, musculoskeletal disorders and pain, but there is limited evidence to support this. The relationship between posture and pain is controversial, but despite the uncertainty, musculoskeletal practitioners routinely evaluate posture and consider posture as a fundamental part of the reasoning process in musculoskeletal therapy. Therefore, assessing and screening posture and range of motion of joints is a method that is functional, and in a seated posture, may be useful for the inactive general population.
REFERENCES


References


References

Deformity Society, And The European Section Of The Cervical Spine Research Society, 14(6), 595-598.


References


Note: For the purposes of completion of this thesis some guidelines of Journal of Bodywork and Movement Therapies [see Appendix C] have not been followed. In order to maintain readability and consistency of format throughout this thesis graphs, figures and tables have been included in the text. Line spacing has been set at 1.5 rather than 2.0, referencing style is adapted to APA rather than journal referencing requirements to maintain consistency with Unitec presentation guidelines. The word limit has been exceeded to demonstrate the scope of work undertaken in this two-part preliminary research and to allow a full and evaluative discussion of the results and further research opportunities of this study.
The development of grading criteria and investigation of single rater test-retest reliability of selected floor sitting postures

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ABSTRACT

Background and objectives
The use of floor sitting postures may provide an alternative to regional orthopaedic examination for evaluation of the musculoskeletal system. No research has yet been conducted on the utility of evaluating floor sitting postures as an indicator of musculoskeletal function. The aims of this study were to: 1) develop grading criteria for floor sitting postures; 2) investigate single rater test-retest reliability of floor sitting postures between sessions.

Methods
Part 1 - Development of grading criteria: An iterative process of development and review was undertaken to select appropriate floor sitting postures; identify performance variables for each posture; describe and refine criteria of performance quality; and develop a grading scale to evaluate the quality of performance for each posture.

Part 2 - A repeated measures design was employed to investigate single rater test-retest reliability of the postures. A sample of 33 healthy participants (n=23F, n=10M) were recruited from the general population. Participants attended two sessions within a 7 to 14-day interval. Anatomical landmarks were marked on each participant with titanium dioxide and self-adhesive markers. Participants performed 3-trials of six defined floor sitting postures in each session. Postures were recorded using digital video in two views; anterior and lateral. Still frames for each posture were captured and analysed. Postural dimensions were measured on each frame. The mean of the postural dimensions for 3-trials of each session was used to analyse the reliability of posture between sessions.

Results
Part 1 - The final grading criteria included six variations of floor sitting postures. A grading system was developed using a 3-6 point ordinal scale.

Part 2 - Data from 25 participants (n=17F, n=8) was used for analysis by a single rater of test-retest reliability. Inter-session reliability was calculated for each posture dimension using intra-class correlation coefficients (ICC). Postural dimensions for four of the six postures demonstrated high reliability ranging from ‘very high’ (ICC = 0.87; 95% CI 0.71 to 0.94) to ‘nearly perfect’ (ICC = 0.97; 95% CI 0.94 to 0.99). The Straight Leg Sit postural angle of dorsiflexion demonstrated ‘low’ reliability (ICC = 0.67; 95% CI 0.25 to 0.85). The Low Kneel postural angle of hip flexion demonstrated ‘moderate reliability’ (ICC = 0.71; 95% CI 0.37 to 0.87).

Conclusion
A set of grading criteria to evaluate the quality of a defined group of floor sitting postures was developed. Participants in this study demonstrated a reasonable level of consistency in achieving postures between two sessions over a 7 to 14-day period. Observer reliability of grading floor sitting postures was not part of this study and needs to be investigated to determine the clinical utility of the grading criteria.

Keywords: posture; movement; functional movement; physical examination; musculoskeletal pain; musculoskeletal disorders; ancestral health; screening
An ‘ancestral perspective on health’ has been proposed as a useful framework in which to consider issues of health and longevity ("Ancestral Health Symposium," 2012; Eaton, Konner, & Shostak, 1988). This framework considers health within the context of evolutionary biology and human evolution (Cordain et al., 2005; O'Keefe, Vogel, Lavie, & Cordain, 2011). The basic science of evolutionary biology is built on theories of genetic natural selection through prevailing conditions of human survival, over many generations (Booth, Chakravarthy, & Spangenburg, 2002). Periods through the timescale of human history have gradually moulded human lifestyle and environment starting from the Palaeolithic era (2.5 million years ago) of the hunter-gatherer. The periods of human history that followed the Paleolithic era on an evolutionary time scale are the Agricultural Revolution (circa 16th-19th century), Industrial Revolution (circa 17th-19th century) and Information Revolution (circa 19th century-present) (Walker, Walker, & Adam, 2003).

Over human history through an evolutionary time scale, lifestyle changes in terms of physical activity and diet have been associated with negative implications on health (Cordain et al., 2005; Eaton et al., 1988; Holth, Werpen, Zwart, & Hagen, 2008; O'Keefe & Cordain, 2004; Popkin, 1999). The lifestyle of the hunter-gatherer was considered to be high in physical activity compared to the lifestyles typical of the Agricultural, Industrial and Information Revolutions (Eaton et al., 1988).

From a genetic and ancestral health perspective many authors suggest that the lifestyle changes associated with technological advances over human history have occurred too rapidly for our genome to adapt (Archer & Blair, 2011; Cordain et al., 2005; Eaton et al., 1988; O'Keefe et al., 2011; Williams & Nesse, 1991). Furthermore, it is hypothesised that the modern human genome has remained stable since the Paleolithic era and therefore resembles that of our ancestors (Barbujani & Colonna, 2010; Cordain et al., 2005; O'Keefe et al., 2011; Pritchard, Pickrell, & Coop, 2010; Stover & Caudill, 2008). Subsequently, researchers (Cordain et al., 2005; Eaton et al., 1988; O'Keefe et al., 2011; O'Keefe & Cordain, 2004) and other proponents ("Ancestral Health Symposium," 2012; Le Corre, 2012; Sisson, 2010; Taubes, 2008; Wolf, 2012) suggest that the lifestyle that our ancestors lived may be better genetically suited, than our
present lifestyle. Preliminary evidence suggests that this putative mismatch between our genes and our current environment, is playing a substantial role in the near epidemics of obesity, cardiovascular disease and type II diabetes (O’Keefe & Cordain, 2004).

It is not only systemic disease but also musculoskeletal disorders and dysfunction that are thought to be associated with adverse effects of modern lifestyle. Potential risk factors for poor musculoskeletal health include individual, psychosocial and physical risk factors (Deeney & O’Sullivan, 2009; Halpern, 1992; Leboeuf-Yde, 2004) which are closely linked to modern workplace environments. Musculoskeletal disorders are highly prevalent in industrial societies and appear to be, at least in part, work related (Punnett & Wegman, 2004).

Posture is often assessed by health practitioners as postural aberrations are presumed, but not definitively researched, to be related to musculoskeletal pain. ‘Poor’ posture may be associated with musculoskeletal pain due to mechanical stress and strain on innervated anatomical structures (Watson, 1983). Clinically, practitioners have described a number of postural aberrations such as ‘forward head posture’ (Darnell, 1983; Silva, Punt, & Johnson, 2010; Yip, Chiu, & Poon, 2008), a flexed lumbar spine while sitting (Bridger, Orkin, & Henneberg, 1992; Corlett, 2008; During, Goudfrooij, Keessen, Beeker, & Crowe, 1985; Harkness, Macfarlane, Silman, & McBeth, 2005; Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999; Vergara, Page, & Sancho, 2006); and muscle properties of decrease in muscle strength, endurance (Bousema, Verbunt, Seelen, Vlaeyen, & André Knottnerus, 2007) and impaired flexibility (Hellsing, 1988). These postural aberrations and negative effects of modern lifestyle have multifactorial and complex aetiology, which further compounds the investigation of cause and effect relationships between musculoskeletal pain, postural aberrations and muscle endurance, strength and flexibility.

Osteopaths and physical therapists routinely assess posture and ‘poor’ posture is commonly associated with pain and dysfunction, despite limited research (Ward et al., 2003). Assessment of posture is a routine component of physical examination and informs diagnosis, treatment and subsequent management (Seidel, Ball, Dains, & Benedict, 2006). Posture assessments normally include observation of static postures either in a standing or sitting position and are assessed alongside observation of joint movement. Health professionals who assess the musculoskeletal system often use isolated orthopaedic tests as part of their examination (Conable & Rosner,
An apparent limitation of isolated orthopaedic tests is that they provide little information about the quality of movement and integration within, and between body regions.

A ‘global’ approach of assessing the musculoskeletal system is suggested by many authors (Reiman, Bolgla, & Lorenz, 2009; Wainner, Whitman, Cleland, & Flynn, 2007; Ward et al., 2003) as a method of assessing the whole body’s function while integrating multiple muscles and joints. This global approach is usually considered when ‘screening’ an individual in some modes of practice such as osteopathy and physical therapy. ‘Screening’ can be described as a method to evaluate risk and protect an individual from injury. A systematic approach of ‘scanning, screening and segmentally defining’ has been taught to osteopaths as part of curriculum (Dummer, 1999; Greenman, 1996; Seffinger, Hruby, & 2007).

‘Functional movement’ has been defined as “purposeful movements associated with common task related activities” (Durward, Baer, & Rowe, 1999) and the term has been used to describe movements and tasks that pertain to sporting or daily activities (Mottram & Comerford, 2008). Examples of functional movements include squatting, lunging or forward bending (Liebenson & Yeomans, 1997). In contrast to isolated orthopaedic testing ‘functional movement screening’ or whole body function assessment is a method used by physical and exercise therapists to ‘screen’ and assess movement and function of the whole musculoskeletal system (Gabbe, Bennell, Wajswelner, & Finch, 2004; Mottram & Comerford, 2008).

‘Screening’ can be operationally defined as a method to assess and identify dysfunction and risk to injury. It has become common that athletes are assessed using pre-participation screening (Carek & Hunter, 2001; Hayen, Dennis, & Finch, 2007) and functional movement screens (Cates & Cavanaugh, 2009; Cook, Burton, & Hoogenboom, 2006). Whole body function assessments are developed with grading systems for objective assessment of quality of movement, diagnostic purposes and injury prediction (Lombardo & Badolato, 2001). The Functional Movement Screen (Cook et al., 2006), Movement Competency Screen (Kritz, 2009), Star Excursion Balance Test (Munro & Herrington, 2010; Plisky, Rauh, Kaminski, & Underwood, 2006) are some examples of movement based systems that have been described for objective assessment of musculoskeletal quality.

Consistent with systems for the evaluation of movement quality, Beach (2010) a New Zealand osteopath and author, has advocated a screening approach using floor sitting postures which include squatting, cross-legged sitting and kneeling. The postures are suggested to be functional,
in that they integrate multiple joints and muscles simultaneously (Beach, 2010). Beach assesses the postures statically and dynamically (moving from one posture to another) for the purpose of assessment of musculoskeletal disorders.

Beach (2010) utilises these postures for screening, diagnosis and therapeutic rehabilitation. However, to date there is no research investigating floor sitting postures in a clinical or functional screening context. In particular research into the validity and reliability of this approach is yet to be undertaken. Currently, the evaluation of these postures lacks well defined grading criteria. Without grading criteria, a high level of subjectively is involved in assessment of the postures and may lead to inconsistent clinical decision making. Assessing static posture may be relevant in those populations whose lifestyles are largely inactive. Beach suggests that assessment of floor sitting postures may provide clinically useful information about kinematics of multiple regions including the lower limb and spine. Beach also suggests that most people who have adapted to a modern lifestyle are unable to sit in these floor sitting postures, however, no normative data is available to inform this view.

Therefore, to progress work in the area of considering the clinical utility of floor sitting postures, the **Aim** of this investigation is to:

1) develop objective grading criteria for selected floor sitting postures; and

2) to investigate single rater test-retest reliability of the floor sitting postures over a 7 to 14-day interval.
2. METHODS

This research project has been divided into two parts. Part 1 outlines the method for developing grading criteria for floor sitting postures, and Part 2 explains the single rater test-retest reliability study for the floor sitting postures.
2.1. METHODS PART 1

Development of grading criteria for floor sitting postures

2.1.1. Design

Use of an iterative process for developing grading criteria for floor sitting postures.

2.1.2. Criteria development

2.1.2.1. Selection of postures

Seven static postures described by Beach (2010) were all considered when determining which postures would be appropriate for the grading criteria. Posture selection was conducted in consultation with a reference group (researcher and 3-advisors) using workshop style meetings where different postures were considered and either retained, rejected or modifications added. Consensus of the reference group was attained for retention and modifications of postures selected for the grading criteria. Beach’s physical examination includes both static and dynamic assessment of posture, however, the scope of this study was to develop grading criteria for static floor sitting postures only.
2.1.2.2. **Development of performance variables and criteria**

To develop the grading criteria components, descriptors described by Beach for performing each posture were drawn upon. The ‘Grading Criteria’ of the floor sitting postures include all components of: ‘performance variables’, ‘performance criteria’ and grading (Figure 3A). A ‘performance variable’ can be defined as a label for a selected postural dimension (e.g., ‘Femur angle from vertical’ see Figure 3B). For each performance variable ‘performance criteria’ were developed and are defined as qualitative descriptors for a selected postural dimension (Figure 3C).

To explain these terms an example of the Squat Grading Criteria is illustrated in Figure 3.

![Figure 3 - Example of naming the components of the grading criteria](image-url)
Performance variables were defined using anatomical landmarks and angles which were considered important physical assessment postural dimensions. Performance criteria were described with an assessment rubric assigned to each performance criteria. An ordinal grading scale between 1 and 5 was attributed to performance criteria (Figure 3D). Depending on the complexity of the postures some performance criteria utilised an ordinal scale ranging between 2 to 5 points. Discrimination between each performance criterion was carefully assessed for clarity in an attempt to minimise ambiguity.

2.1.2.3. Process of criteria development

An iterative process was used to develop preliminary and draft grading criteria. Modification and refinements of the Grading Criteria components were done through practical field trials, reviewing photographs and a consensus process integrated into reference group discussions. The development of preliminary and draft grading criteria was complemented by repeatedly reviewing the following aspects throughout the developmental process:

- Face validity: whether the criteria were likely to measure what they intended to measure
- Content validity: whether the criteria considered important components related to musculoskeletal screening
- Practical applicability: whether the criteria were applicable in the clinical environment

For the draft grading criteria discussion and refining processes took place with the reference group. Additional to reference group discussion, feedback from colleagues and physical therapists were sought for further refining of the draft grading criteria. The final Grading Criteria were tabulated and diagrams added to represent examples of performance criteria and grading of the floor sitting postures.
2.2. METHODS PART 2

Single rater test-retest reliability of the postures

2.2.1. Participants

Volunteers were recruited using convenience sampling methods (posters, flyers and word-of-mouth) from the general population. Inclusion criteria were: 18 years or older; Exclusion criteria were: had no clinical signs or symptoms of serious illness (fracture, infection, cancer or other pathology); were currently experiencing acute pain; had a diagnosis of rheumatological condition; were pregnant; and were currently receiving manipulative or other bodywork therapy. All participants read an Information Sheet, provided written consent and completed a Profile Form containing questions in relation to demographics, medical history, injury, pain and activity level [Ethics forms-Appendix A]. The participants were enrolled in the study after providing written informed consent. The study was approved by the Unitec Research Ethics Committee (Registration Number: 2010-1136).

2.2.2. Design

A single rater test re-test repeated measures design was employed. Participants attended two sessions with an interval of 7-14 days between sessions. This interval was intended to be representative of the interval between consultation sessions in clinical practice. Each participant was measured at approximately the same time of day (±3 hr) at each session. The study schema is shown in Figure 4.
Methods

A) Recruitment
n=33 participants, 8 dropouts. Final n=25 participants used for data analysis

B) 1st Session
Participant attended 1st session of performing postures

D) 2nd Session
Participant attended 2nd session of performing postures

D) Data extraction and analysis
Photographs marked with postural dimensions using SiliconCOACH software

E) Test-retest reliability
ICCs calculated for each variable and compared between the 2 sessions

FIGURE 4- SCHEMA TO DEMONSTRATE THE FLOW OF STUDY PROCEDURES
2.2.3. Laboratory Set up

A data collection area was established in a sports laboratory with reference markers fixed to the floor and cameras set at right angles. Video cameras and tripods (Camera A; Sony model number DCR-HC40E; and Camera B; Panasonic model number NV-DS88A) were positioned to ensure the entire participant and floor reference markers were visible in all fields of views (anterior and lateral). A 50cm length of adhesive tape was aligned on an exercise mat for participants to use as a reference point to ensure alignment with the cameras. The video cameras and tripods were placed at 80cm above ground level. A spirit level and tape measure was used to ensure the correct orientation of camera positioning between recordings. Tripods were secured to the floor to prevent a change in camera position between sessions.

2.2.4. Procedure

When the participants attended the first session, they were oriented to the procedures required, along with postures illustrated in an introductory video. Six postures include, and were performed in the following sequence by each participant: Squat; Squat Variation; Straight-Leg Sit; Cross-Legged Sit, Low and High Kneel (Figure 6, 1-6). The postures were performed in a defined sequence for every trial, commencing from a standing position to performing the postures, to standing again as outlined in the instruction sheet. To aid the accuracy of the assessment of all the postures, and to improve reliability testing, anatomical landmarks were located and marked with: titanium dioxide (TiO$_2$) or ‘correction fluid’ (Pentel Co. Ltd., Japan); self-adhesive markers (19 mm in diameter); and plastic fin markers over selected spinous processes.

To ensure marked landmarks could be captured on video, males wore shorts and their trunks were bare while females wore shorts and a singlet. Self-adhesive markers and fin markers were placed on the left hand side of the body and were located on landmarks which include: lateral malleoli, fibular head, greater trochanter, acromion and both tibial tuberosities. Fin markers placed on the spinous processes at levels L5 or L4 in the lumbar spine, T12 along the thoracic spine, C7 along the cervical spine (Figure 5). These landmarks were chosen due to ease of finding the location and ease of visualisation.
**Methods**

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SQUAT VARIATION POSTURE AS AN EXAMPLE OF MARKER PLACEMENT

I) (A) Anterior acromioclavicular (AC) joint; (B) Greater trochanter; (C) Fibular head; (D) Lateral maleoli; (E) Tibial tuberosities

Il) Custom made plastic fin markers (60 mm long) were positioned over the spinous processes of the C7, T12 and L5/L4 vertebral levels. Note: the images shown here are stills captured from video and proportions are skewed in these images.

**FIGURE 5** - IMAGE TO DEMONSTRATE PLACEMENT OF MARKERS

---

2.2.4.1. Instructions

Instructions were developed mainly using the descriptors from Beach (2010). A standardised set of instructions were given to each participant (Figure 6) for performing the postures, in addition the postures were visually demonstrated. If postural deviations or incorrect posture was observed and persisted after repeating instructions three times, minimal cuing was used. Participants held each posture for a count of 3s which was verbalised by the researcher. The ‘High Kneel’ was held for 30s. The ‘Straight Leg Sit’ dorsiflexion angle was controlled for with a box, and participants were instructed to keep feet against the box to maintain a 90° angle (Figure 6, posture 3). Each participant performed the six floor sitting postures for 3-trials in each session. Each trial was separated by an interval of 60s during which time the participant walked at a leisurely pace around the room. No warm-up or stretching exercises were performed by the participants prior to the testing sessions in an attempt to more closely replicate the manner in which clinical evaluation is routinely practiced. Each participant was instructed to look ahead while holding the postures to maintain frontal and lateral positioning.
Methods

1) Squat
   1. Toes on line and feet a comfortable hip width apart
   2. Arms 90° in front of body
   3. Bend hips, knees and ankles and go as low as you can

2) Squat Variation
   Repeat squat instructions but with arms behind back (once in seemingly static position participant asked to place hands lower down for visibility of markers)

3) Straight Leg Sit
   1. Sit on the floor with equal weight on your sitting bones
   2. Place feet against box and straighten legs, keep feet and toes together
   3. Hold onto elbows
   4. Straighten spine into an upright position making sure knees don’t bend

4) Cross-Legged Sit (right & left leg)
   1. Place one ankle marker on black line
   2. Place other foot on knee and align toes to make a vertical line with knees
   3. Sit up straight and evenly onto sitting bones, hold onto elbows

5) Low Kneel
   1. Knees on black line with toes pointing backwards
   2. Sit backwards onto heels with a straight back, hold onto elbows

6) High Kneel
   1. Tuck toes in as much as possible
   2. Keep knees together and sit onto heels with a straight back

FIGURE 6- INSTRUCTIONS AND ILLUSTRATION OF PERFORMING THE FLOOR SITTING POSTURES
2.2.5. Data Management and Analysis

2.2.5.1. Video digitization

Lateral (left hand side of participant) and anterior views were recorded simultaneously. To minimise error with video handling, the participants were recorded for the whole of one session without stopping the video. Durations of video recording for each subject varied between 15 to 25 minutes per session.

A still photograph from the video footage for each trial of a posture was analysed using SiliconCOACH (SiliconCOACH, Dunedin, N.Z.). The still photograph was extracted from footage at a point where the participant appeared static. Postural dimensions were determined by the measurement of distances and angles between anatomical landmarks (Figure 7). Each photograph was overlayed and marked with the appropriate postural dimensions in both the anterior and lateral view. A total of 26 postural dimensions were measured for each participant and each session. Raw data was tabulated in a spreadsheet. For each postural variable, the mean value was calculated for each session and used to assess between session reliability of the postural dimensions.

2.2.5.2. Reliability of data extraction

An additional reliability test-retest study was performed to estimate measurement errors associated with the operator’s use of software programme Silicon COACH. A total of 26 postural dimensions of the postures were assessed six times in total, with a one week interval between tests. The operator was blinded to prior result findings of each postural dimension. The intra class correlation coefficient (ICC) for repeated measurement of postural dimensions were ‘nearly perfect’ (ICC = 1.0; 95% CI 0.97 to 1.0)
Methods

FIGURE 7 - POSTURAL DIMENSIONS FOR EACH POSTURE

Typical overlay of image for variable measurement. (i) Squat angles: A) Dorsiflexion of ankle, B) Knee flexion, C) Hip flexion, D) Lumbar angle; (ii) Squat variation angles: A) Dorsiflexion of ankle, B) Knee flexion, C) Hip flexion, D) Lumbar angle; (iii) Squat and squat variation: A) Distance between ankles, B) Distance between knees; (iv) Straight-leg sit angles: A) Dorsiflexion of ankle, B) Lumbar angle; (v) Cross-legged sit: Distance of knee from floor; (vi) Cross-legged sit: Lumbar angle; (vii) Low kneel angles: A) Dorsiflexion of ankle, B) Knee flexion, C) Hip flexion, D) Lumbar angle; (viii) High kneel angles: A) Dorsiflexion angle, B) Kneel flexion, C) Lumbar angle, D) Toe extension width. Note: the images shown here are stills captured from video and proportions are skewed in these images.
2.2.6. Data Analysis

2.2.6.1. Contrasts of Squat and Squat Variation

Paired sample t-tests were used to consider differences in performance variables between Squat and Squat Variation. Mean differences and their 95% confidence intervals were calculated. All statistical analysis was conducted using SPSS (v.18; SPSS, IBM, New York, USA).

2.2.6.2. Test-retest reliability

To evaluate test-retest reliability across sessions, postural dimension values for each performance variable were compared between the two sessions. Comparison statistics are reported as intra class correlation coefficients for continuous variables with normal (or approximately normal) distributions (Hopkins, 2003). The mean of 3-trials for each performance variable from each session was used for analysis. Reliability coefficients (ICCs) were calculated for each postural variable together with 95% confidence intervals using SPSS (v.18; SPSS, IBM, New York, USA). The fixed model for absolute agreement was used.

To interpret reliability coefficients the qualitative descriptors of Hopkins (2000) were used (Table 1). Descriptors were applied using a conservative approach based on the lower limit of the confidence interval. ‘Acceptable reliability’ was operationally defined as the lower limit of the ICC > 0.5.

<table>
<thead>
<tr>
<th>Correlation Coefficient</th>
<th>Descriptor Synonyms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 0.1</td>
<td>‘very small’</td>
</tr>
<tr>
<td>0.1 – 0.3</td>
<td>‘low’</td>
</tr>
<tr>
<td>0.3 – 0.5</td>
<td>‘moderate’</td>
</tr>
<tr>
<td>0.5 – 0.7</td>
<td>‘high’</td>
</tr>
<tr>
<td>0.7 – 0.9</td>
<td>‘very high’</td>
</tr>
<tr>
<td>0.9 – 1</td>
<td>‘nearly perfect’</td>
</tr>
</tbody>
</table>
3. RESULTS

This results section has been divided into two parts. Part 1 outlines the results of developing grading criteria for floor sitting postures, and Part 2 explains the results of the single rater test-retest reliability study for the floor sitting postures.
3.1. RESULTS PART 1

Grading Criteria Development

3.1.1. Posture selection and grading

From Beach’s (2010) seven original floor sitting postures, six variations of postures were included in the grading criteria (Figure 8). The postures included in the grading criteria were: Squat, Squat Variation, Straight Leg Sit, Cross-Legged Sit, Low Kneel and High Kneel. Postures omitted on the observed basis of insufficient clinical practicality and functionality for this study include the: Drinking posture (foetus position), Cowboy posture (kneeling with one leg up) and Side Saddle posture (both heels to one side). These postures were also omitted due to being duplicates or having little variation from the chosen postures to be included in the grading criteria. Further to this the omitted postures were observed by the researcher and advisors to add limited value to the investigation, but cannot be discounted for further research. The Squat Variation posture was added to explore the effect of arm positioning on joint dynamics between the Squat and the Squat variation. The Squat Variation was not a posture Beach described. The criteria for each posture excluded any movement components such as the quality of transition between static postures.

The developed Grading Criteria utilises a grading scale between 0-5. When a participant was not able to perform the posture, or reported pain while performing the posture a grade of 0 was assigned. Grades between 1 to 5 are assigned based on increasing levels of quality, where 1 is the lowest order criteria and 5 represents the highest or best example of a posture. Some performance variables in the Grading Criteria utilise a 4-point scale which has been used in other grading criteria for assessment of functional movement (Cook et al., 2006).
Grading Criteria For Floor Sitting Postures

1. **SQUAT and SQUAT VARIATION**
   A) Femur angle from vertical
   Rate the angle of the femur according to the hours of the clock in a clockwise direction. Middle of the clock positioned mid-knee. Rate to the nearest number and rate down numerically if the femur appears to be half way between the numbers on the clock.
   Squat Criteria:
   1. Femur appears to be at 1 o'clock
   2. Femur appears to be at 2 o'clock
   3. Femur appears to be at 3 o'clock
   4. Femur appears to be at 4 o'clock
   5. Femur appears to be at 5 o'clock

C) Head Position
   Head position: Vertical line from mid-ear to floor
   Head Position Criteria:
   1. Vertical line from mid-ear falls outside of the foot
   2. Vertical line from mid-ear falls within the foot

B) Torso–tibial relationship in terms of convergence
   Convergence is the intersection of the extrapolated lines from the angles of the tibia and tibia.
   Convergence Criteria:
   1. Convergence above pelvis
   2. Convergence below pelvis
   3. No obvious convergence, the torso and tibia appear parallel

D) Tibial tuberosity and 2nd toe
   Description: Location of the tibial tuberosity in relation to the toes in the frontal plane.
   Tibial Tuberosity and 2nd Toe Criteria:
   1. Vertical line from the tibial tuberosity does not bisect any of the toes
   2. Vertical line from the tibial tuberosity bisects any of the toes except the 2nd toe
   3. Vertical line from the tibial tuberosity bisects the 2nd toe

3. **STRAIGHT-LEG SIT**
   Straight-Leg Sit Criteria:
   1. Knees are bent with calf not in contact with the floor and/or curved back
   2. Straight legs with back straight but not vertical
   3. Straight legs with back straight and vertical

4. **CROSS-LEGGED SIT**
   Grading in reference to the distance of the superior aspect of the knee of the top leg from the floor. Foot length in this criterion refers to a measurement between 20-30 centimeters.
   Cross-Legged Sit Criteria:
   1. Can't do posture, knee is more than a foot length high from the floor
   2. Knee held noticeably above lower leg less than a foot length high from the floor, and legs are not in contact
   3. Legs appear to be in contact with top leg rested on lower limb

5. **LOW KNEEL**
   Low Kneel Criteria:
   1. Buttock does not rest on heels and/or gap present under the ankle
   2. Buttock rests on heels but without a straight and vertical back
   3. Buttock rests on heels with a straight and vertical back

6. **HIGH KNEEL**
   A) Buttock to Heel contact
   Thigh-calf contact is in reference to proximal calf
   High Kneel Criteria:
   1. Minimal to no thigh-calf contact, no buttock-heel contact
   2. Mid-thigh and calf in contact, with no buttock-heel contact
   3. Buttock on heels

B) Angle of ankle flexion—angle of planter surface of foot and floor
   Angle of Ankle Criteria:
   1. Planter surface of foot is less than 90° from the floor
   2. Planter surface of foot is vertical (90°) to the floor
   3. Planter surface of foot is more than 90° from the floor

C) Extension of toes
   Extension of toes Criteria:
   1. Toes have minimal extension
   2. Toes are considerably extended

FIGURE 8 - FINAL GRADING CRITERIA FOR SIX FLOOR SITTING POSTURES
3.2. RESULTS PART 2

Single rater test-retest reliability of postures

Thirty three participants met inclusion and exclusion criteria. However, eight participants failed to attend the second session (n=1 injury; n=2 illness; n=5 failure to keep appointment). Only participants who had completed both sessions were included for data analysis (n=25). Participant characteristics are shown in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2- PARTICIPANT CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Female (n=17)</td>
</tr>
<tr>
<td>Male (n=8)</td>
</tr>
</tbody>
</table>

Notes: All data are mean (SD), * Participant self-reported estimates

3.2.1. Contrasts between Squat and Squat Variation postural dimensions

Contrasts for postural dimensions of the Squat and Squat Variation are shown in Table 3. Descriptive data for postural dimensions for all the postures are shown in Appendix B.

A comparison of the mean angle of dorsiflexion for the Squat and Squat Variation was small, statistically significant, but not clinically important. A comparison of the mean angle of hip
flexion for the Squat and Squat Variation revealed no difference between the two squatting postures. Difference between the two squatting postures: Dorsiflexion angle of the Squat (mean ± SD = 61.4 ± 5.9°) and Squat Variation (59.6 ± 6.3°). The difference in mean angle of dorsiflexion between postures was 1.79° (95% CI= 0.9 to 2.7°; paired samples t = 4.1; df = 24; p<0.001). Hip flexion angle of the Squat (mean ± SD = 85.2 ± 12.7°) and Squat Variation (87.0 ± 11.9°). The difference in mean angle of hip flexion angle between postures was -1.80° (95% CI= -4.8 to 1.2°; paired samples t = -1.2; df =24; p=0.23).

A comparison of the mean knee flexion angle for the Squat and Squat Variation revealed that Squat Variation had a larger knee angle (i.e., depth of squat was higher from the ground or knee flexion was less acute) Squat Variation (mean ± SD = 95.1 ± 29.2°) and Squat (77.2 ± 32.7°). The difference in mean knee angle was -17.9° (95% CI= -25.9 to -9.9°; paired samples t = -4.6; df =24; p<0.001).

A comparison of the mean lumbar angle for the Squat and Squat Variation revealed that the Squat had a smaller angle from vertical (i.e., lumbar spine more vertically upright), Squat (mean ± SD = -31.0 ± 17.8°) and Squat Variation (-46.4 ± 21.0°). The difference in mean lumbar angle was 15.3° (95% CI= 9.3 to 21.3°; paired samples t = 5.3; df = 24; p<0.001).

A comparison of the mean width between left and right knee and left and right ankle for the Squat and Squat variation revealed no substantial difference between the two squatting postures: Inter-knee width of the Squat (mean ± SD = 24.8 ± 8.0cm) and Squat Variation (24.5 ± 5.6cm). The difference in mean inter-knee width between squat postures was 0.3cm (95% CI= -1.9 to 2.6cm); paired samples t = 0.3; df =24; p=0.76). Inter-ankle width for each squatting posture was: Squat (13.5 ± 5.6cm) and Squat Variation (13.9 ± 5.0cm). The difference in mean width between left and right ankle between squat postures was -0.4cm (95% CI= -1.8 to 1.0cm; paired samples t = -0.6; df =24; p=0.55).
### TABLE 3- CONTRASTS OF THE SQUAT AND SQUAT VARIATION POSTURAL DIMENSIONS

<table>
<thead>
<tr>
<th>Variables</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Squat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion of ankle</td>
<td>24.33</td>
<td>45.33</td>
<td>69.67</td>
<td>61.43</td>
<td>5.94</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>104.00</td>
<td>31.00</td>
<td>135.00</td>
<td>77.19</td>
<td>32.68</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>57.00</td>
<td>62.67</td>
<td>119.67</td>
<td>85.22</td>
<td>12.70</td>
</tr>
<tr>
<td>Lumbar angle</td>
<td>61.67</td>
<td>-66.00</td>
<td>-4.33</td>
<td>-31.03</td>
<td>17.82</td>
</tr>
<tr>
<td>Distance between knees</td>
<td>38.03</td>
<td>0.30</td>
<td>38.33</td>
<td>24.79</td>
<td>8.04</td>
</tr>
<tr>
<td>Distance between ankles</td>
<td>23.84</td>
<td>0.16</td>
<td>24.00</td>
<td>13.45</td>
<td>5.65</td>
</tr>
<tr>
<td><strong>Squat Variation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion of ankle</td>
<td>23.67</td>
<td>44.00</td>
<td>67.67</td>
<td>59.63</td>
<td>6.29</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>95.33</td>
<td>38.33</td>
<td>133.67</td>
<td>95.14</td>
<td>29.16</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>56.00</td>
<td>73.33</td>
<td>129.33</td>
<td>87.03</td>
<td>11.86</td>
</tr>
<tr>
<td>Lumbar angle</td>
<td>84.33</td>
<td>-84.00</td>
<td>0.33</td>
<td>-46.36</td>
<td>20.99</td>
</tr>
<tr>
<td>Distance between knees</td>
<td>23.67</td>
<td>14.33</td>
<td>38.00</td>
<td>24.46</td>
<td>5.60</td>
</tr>
<tr>
<td>Distance between ankles</td>
<td>20.67</td>
<td>3.00</td>
<td>23.67</td>
<td>13.86</td>
<td>5.03</td>
</tr>
</tbody>
</table>
3.2.2. *Intraclass-correlation-coefficient results for each postural dimension*

Reliability coefficients for each of the postural dimensions for each posture are shown in Table 4. Postural dimensions for four of six postures, including the postural dimensions of the Squat and Squat Variation, demonstrated high reliability between sessions ranging from ‘very high’ (ICC = 0.87; 95% CI 0.71 to 0.94) to ‘nearly perfect’ (ICC = 0.97; 95% CI 0.94 to 0.99). The postural measurement of ankle dorsiflexion in the Straight-Leg Sit showed low reliability and a wide confidence interval (ICC = 0.67; 95% CI 0.25 to 0.85). Hip flexion postural measurement for the Low Kneel demonstrated moderate reliability with a wide confidence interval (ICC = 0.71; 95% CI 0.37 to 0.87). Lumbar angle demonstrated at least ‘high’ reliability for all postures across both sessions.
TABLE 4- INTRACLASS CORRELATION COEFFICIENT (ICC) VALUES FOR EACH POSTURAL DIMENSION

<table>
<thead>
<tr>
<th>Variables</th>
<th>ICC</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Squat</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion of ankle</td>
<td>0.93</td>
<td>0.83</td>
<td>0.97</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>0.96</td>
<td>0.92</td>
<td>0.98</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>0.92</td>
<td>0.83</td>
<td>0.96</td>
</tr>
<tr>
<td>Lumbar angle</td>
<td>0.97</td>
<td>0.94</td>
<td>0.90</td>
</tr>
<tr>
<td>Distance between knees</td>
<td>0.96</td>
<td>0.91</td>
<td>0.98</td>
</tr>
<tr>
<td>Distance between ankles</td>
<td>0.93</td>
<td>0.84</td>
<td>0.98</td>
</tr>
<tr>
<td><strong>Squat Variation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion of ankle</td>
<td>0.94</td>
<td>0.87</td>
<td>0.97</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>0.97</td>
<td>0.92</td>
<td>0.98</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>0.87</td>
<td>0.74</td>
<td>0.95</td>
</tr>
<tr>
<td>Lumbar angle</td>
<td>0.97</td>
<td>0.94</td>
<td>0.99</td>
</tr>
<tr>
<td>Distance between knees</td>
<td>0.89</td>
<td>0.76</td>
<td>0.95</td>
</tr>
<tr>
<td>Distance between ankles</td>
<td>0.95</td>
<td>0.79</td>
<td>0.96</td>
</tr>
<tr>
<td><strong>Straight Leg Sit</strong></td>
<td></td>
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</tr>
<tr>
<td>Dorsiflexion angle*</td>
<td>0.67</td>
<td>0.25</td>
<td>0.85</td>
</tr>
<tr>
<td>Lumbar angle*</td>
<td>0.84</td>
<td>0.64</td>
<td>0.93</td>
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<tr>
<td><strong>Cross-Legged Sit (Right Leg)</strong></td>
<td></td>
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</tr>
<tr>
<td>Lumbar angle</td>
<td>0.97</td>
<td>0.93</td>
<td>0.99</td>
</tr>
<tr>
<td>Distance of knee to floor</td>
<td>0.97</td>
<td>0.92</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>Cross-Legged Sit (Left Leg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar angle</td>
<td>0.87</td>
<td>0.71</td>
<td>0.94</td>
</tr>
<tr>
<td>Distance of knee to floor</td>
<td>0.96</td>
<td>0.86</td>
<td>0.98</td>
</tr>
<tr>
<td><strong>Low Kneel</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Dorsiflexion angle</td>
<td>0.89</td>
<td>0.75</td>
<td>0.95</td>
</tr>
<tr>
<td>Kneel flexion</td>
<td>0.89</td>
<td>0.76</td>
<td>0.95</td>
</tr>
<tr>
<td>Hip flexion*</td>
<td>0.71</td>
<td>0.37</td>
<td>0.87</td>
</tr>
<tr>
<td>Lumbar angle*</td>
<td>0.81</td>
<td>0.59</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>High Kneel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion angle</td>
<td>0.90</td>
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<td>0.96</td>
</tr>
<tr>
<td>Toe extension</td>
<td>0.89</td>
<td>0.71</td>
<td>0.95</td>
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<tr>
<td>Knee flexion</td>
<td>0.93</td>
<td>0.85</td>
<td>0.97</td>
</tr>
<tr>
<td>Lumbar angle</td>
<td>0.94</td>
<td>0.90</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Notes: Descriptors from Hopkins (2000) are interpreted conservatively based on the lower limit of the confidence interval; *Results of importance (see discussion)
4. DISCUSSION

This discussion section has been divided into two parts. Part 1 outlines the discussion for development of grading criteria for floor sitting postures, and Part 2 discusses the single rater test-retest reliability study for the floor sitting postures.
To date there has been almost no research investigating the potential utility of floor sitting postures and static functional screens in both a clinical and functional screening context. To the author’s knowledge, this study represents the first attempt at developing grading criteria for these postures and the first to investigate their inter-session reliability.

4.1. DISCUSSION PART 1

Grading criteria development

The development of grading criteria was undertaken to reduce subjectivity in the clinical assessment of floor sitting postures. Six floor sitting postures were used to develop the Grading Criteria and were, with the exception of the Squat Variation, based largely on Beach (2010) descriptions.

The Grading Criteria includes two versions of a squat position: standard Squat; and Squat Variation. The Squat Variation includes both arms placed behind the back, as opposed to the standard Squat where arms are placed horizontally in front of the body (Dionisio, Almeida, Duarte, & Hirata, 2008; Kritz, Cronin, & Hume, 2009; Liebenson, 2003; Miletello, 2010). The squat is used in assessment, therapy, and performance enhancement in physical therapy (Liebenson, 2007), exercise therapy (Cook et al., 2006; Kritz et al., 2009) and sports medicine (Brukner & Khan, 2009, p. 429; Liebenson, 2007). The multi-articular and functional nature of the squat provides information about joint kinematics and quality of movement such as mobility within the ankles, knees, hips, and spine.

The postures in this study are complex and place particular demands on an individual and can be termed as being ‘technically difficult’. ‘Technical difficulty’ can be considered as physically challenging or requiring high levels of mobility and stability. The squat can be a technically difficult movement and therefore within a screening context, the squat provides the opportunity for faulty movement patterns and compensations to be recognised (Butler, Plisky, Southers, Scoma, & Kiesel, 2010). There appears to be widespread agreement that the squat is
both an important static posture, and movement pattern, and provides valuable information about physical function.

The Squat Variation was included so as to consider the influence of arm positions (anterior and posterior) on posture and the subsequent shifts of the centre of mass on lower extremity joint angles. The Squat Variation appeared to involve greater physical demands compared to the Squat in terms of adjusting for the centre of mass and resulted in participants achieving a more horizontally oriented trunk. The technical difficulty of the Squat Variation lends itself to use in people with higher levels of physical competency and may be clinically helpful in discriminating more subtle dysfunctional movement patterns affecting posture, which may be undetected in less challenging squat positions.

Inclusion of the Squat Variation in the grading criteria was intended to be a progression of difficulty from the standard Squat as a recent unpublished study by Rondini, Stagni, Fantozi, and Ceciliani (2008) suggests that arm variations are intended to create different limitations on the musculoskeletal chain, therefore highlighting possible technical difficulty and musculoskeletal compensations. Research on the effect of arm variations on squat performance requires further attention.

4.1.1. Further research on Grading Criteria

Inter Observer reliability of grading the floor sitting postures using the developed Grading Criteria has not been conducted as part of this study. Research needs to be undertaken on this aspect as acceptable observer reliability predicates the utility of the grading criteria in a clinical context. Further evaluation may be needed on all the components of the developed Grading Criteria for floor sitting postures which would help improve the quality of the criteria. Factors that may be reviewed include: posture selection (addition, retention and rejection of postures); grading criteria components (review of posture performance variables and criteria); grading scheme (review of potential summation of scores to reflect overall quality); improving the quality of instructional material for participants undertaking these postures in research (e.g., generation of video or photographic content corresponding to each grade and performance criteria).
Fundamental movements (e.g., flexion-extension, push-pull etc) are the focus of movement-based screening tools such as the Functional Movement Screen (Cook et al., 2006). Each of the seven movements within the Functional Movement Screen appears to correspond to a fundamental movement pattern. In the current study five out of six static postures challenge the fundamental pattern of flexion and to a lesser extent extension. Only the Cross-Legged Sit challenges external and internal rotation of the lower extremity. There are no floor sitting postures in this study that challenge side-bending, rotation/twisting and extension patterns. Consideration of these fundamental movement patterns would need further investigation to move beyond the context of sitting.

4.1.2. General overview of posture performance

On observation, the performance of most of the postures was reasonably achievable by the participants in this sample. All postures were associated with technical difficulty but based on observation and informal feedback from participants, the apparent difficulty in performing the postures ranged from: (most difficulty) Squat Variation>Squat>Cross-Legged-Sit>Straight-Leg-Sit>High Kneel>Low Kneel (least difficulty). This order is based on observation during data collection of posture performance by majority of the sample used for this study. Some participant varied from this order. Formal investigation of the relative difficulty of assuming each posture would be beneficial.

4.1.3. Postural dimensions in this study are not conventional anatomical measurements

Some of the postural dimensions used in this study are not conventional anatomical measurements but, for practical reasons easily accessible landmarks were used for analysis. For example, the fibular head was used rather than the anatomical centre of the knee joint. Therefore, the interpretations of these descriptive results are limited to this study as they are
Discussion

not representative of typical clinical measurements of anatomical angles. The descriptive results are useful for understanding the inter-session variability limited to this study.

4.1.4. Contrast between postural dimensions for Squat and Squat Variation

The kinematics and kinesiology of the squat posture are known to be complex (Dionisio et al., 2008). In this study only joint mobility at end range of static posture was measured therefore representing a partial biomechanical picture of static posture. The order of joint movement for both the Squat and Squat Variation may vary due to differences in mobility between individuals and their personal idiosyncrasies. The requirements to achieve and maintain a static squat posture may include: 1) adequate dorsiflexion of ankle range; 2) adequate active contraction of muscles involved with maintaining dorsiflexion (e.g., tibialis anterior); 3) adequate hip and lumbar flexion. There was no practical difference in dorsiflexion and hip flexion angles between Squat and Squat Variation. However, lumbar flexion and knee flexion angles were greater for Squat Variation.

In terms of mobility, the Squat Variation demonstrated less depth than the Squat. The Squat Variation has an arm position that is posterior to the back and compared to the Squat posture, the Squat Variation has a more posterior centre of mass resulting in a more demanding posture. The posterior shift in centre of mass was compensated by increased trunk flexion coupled with less depth of the squat. The Squat Variation may be a clinically useful progression from the Squat because it requires greater joint mobility and therefore may be useful in identifying functional characteristics that are not apparent in the less demanding Squat.
4.2. DISCUSSION PART 2

Single rater test-retest reliability study

The inter-session reliability of posture must be known in order to determine posture variability. Four postures in this study demonstrated acceptable levels of reliability between sessions. Two postures, Straight Leg Sit and the Low Kneel, demonstrated poor reliability between sessions and these will be the focus of the following discussion. Sources of variability that relate to all postures will also be considered.

4.2.1. Internal validity affecting reliability of the postures

The postures in this study required varied demands on the musculoskeletal system. Some of the postures are inherently more difficult to achieve than others. For example, the Squat or the Straight Leg Sit have higher technical difficulty and appear to require more effort to maintain the posture, whereas the Low Kneel is likely to have less technical difficulty requiring less effort to maintain the posture. Participant motivation and tolerance of discomfort associated with the postures are therefore factors that can contribute to the reproducibility of posture, regardless of biological or natural variation. Surprisingly, and despite the attempt to control dorsiflexion angle of the Straight Leg Sit between sessions, less than acceptable reliability was observed. Straight Leg Sitting with the foot at 90° is known to increase neurodynamic tension and can be uncomfortable (Cleland, Childs, Palmer, & Eberhart, 2006). This may be attributable to alterations in participant motivation and tolerance of discomfort between sessions. The Straight Leg Sit performed without controlling ankle dorsiflexion may be interesting to investigate the reproducibility of the posture. The Straight Leg Sit may have other sources of variation such as natural or systematic variation.
It is challenging to identify all the possible sources of variability and bias within a study. In the current study both natural variation (random error) and systematic variation (measurement error) may be possible sources of variation. Natural variation is considered to be the biological variation within an individual, as it is known that even apparently stable biological characteristics often show small day to day differences, or follow a circadian rhythm (de Vet, Terwee, Knol, & Bouter, 2006). Natural variation may be operant in all postures but the extent of variation may be greater in some postures more than others. The potential sources of variation for the Straight Leg Sit and the Low Kneel that demonstrated less than acceptable reliability for some postural dimensions are discussed in the next sections.

4.2.1.1. Reliability of Straight Leg Sit

On a superficial level the Straight Leg Sit appears similar to the Sit-and-Reach test. For example, the Straight Leg Sit is similar in appearance and posture set-up to the Sit-and-Reach test, including 90° dorsiflexion of the ankle, full knee extension, hip flexion and varied angles of lumbar flexion. The posture setup in the Straight Leg Sit, and the Sit-and-Reach test, both lengthen the ‘posterior muscular chain’ (inter-connection of posterior leg and back muscles) and involve a comparable level of technical difficulty to perform. An important difference between these tests is that for the Straight Leg Sit the quality of posture is observed rather than a single outcome measure of reach distance which is typically determined for the Sit-and-Reach test. High inter-session reliability has been demonstrated for the Sit-and-Reach test (Ayala, Baranda, Croix, & Santonja, 2011; Gabbe et al., 2004). Due to outcome measures being different between the Sit-and-Reach test and the Straight Leg Sit, despite similar appearance, results cannot be directly compared. However, the Straight Leg Sit in this study demonstrated low reliability compared to the well established reliability of the Sit-and-Reach test (Ayala et al., 2011). Possible sources of variation for the Straight Leg Sit postural dimensions may include: natural variation of tissue extensibility of the posterior muscular chain and low adherence of the participant following instructions.

High technical difficulty is likely to be associated with the Straight Leg Sit due to the requirement of maintaining ankle dorsiflexion, knee extension, hip flexion and a vertical lumbar spine. This can be physically demanding for many participants and may require high levels of motivation for
performing the posture in a similar manner for each trial. Motivation levels can vary between sessions as evidence suggests psychological state or mood can affect postural control (Kitaoka, Ito, Araki, Sei, & Morita, 2004). Discomfort is likely to be associated with posterior muscular chain tension in the Straight Leg Sit and can contribute to variability between sessions. Variation in assuming the Straight Leg Sit posture between sessions may be partly explained by known variation between sessions for hamstring muscle extensibility (Ayala et al., 2011). Other confounding variables associated with hamstring flexibility include prior exercise and muscle stretching (Hoskins & Pollard, 2005) and the phase of menstrual cycle for females (Ayala et al., 2011). None of these factors were controlled for in this study.

During data collection, while participants were performing the Straight Leg Sit greater attention was necessary in instructing participants to maintain full ankle dorsiflexion, knee extension and a vertical lumbar spine. Flexing the ankles, knees and hips are strategies that may reduce discomfort from increasing the ‘slack’ in the posterior muscular chain resulting in a less demanding posture. The less demanding posture may cause variation of posture between sessions. There is evidence that demonstrates the influence of ankle positioning on the straight leg raise test for assessing pathology and neural tension in lumbar structures and the posterior neuro-muscular chain (Dixon & Keating, 2000).

Evidence demonstrates that performing the straight leg raise while maintaining ankle dorsiflexion and knee extension resulted in less hip flexion compared to the straight leg raise performed without maintaining ankle dorsiflexion (Boland & Adams, 2000). Therefore, ensuring that instructions are followed by participants is necessary as failure to achieve these postural requirements would contribute to variation of performing the posture between sessions, therein affecting the validity of the results.

4.2.1.2. Reliability of the Low Kneel

The moderate reliability demonstrated for the postural dimension of hip flexion during Low Kneeling may be due to natural variation of the posture but more so to systematic variation. Low technical difficulty is associated with the Low Kneel, with evidence suggesting that during full knee flexion such as kneeling, thigh-calf contact is substantial and is presumed to reduce muscle forces in the knee (Zelle, Barink, Loeffen, De Waal Malefijt, & Verdonschot, 2007). Even
though the Low Kneel may have low technical difficulty, discomfort may be associated with full knee flexion (with or without thigh-calf contact) and full planter-flexion. For the Low Kneel, reproducibility of the posture may be affected by the participants’ ability to tolerate discomfort inherent in the posture. For example, alteration of posture to reduce discomfort can occur in the Low Kneel when leaning the torso forwards possibly reducing weight-bearing on the heels and full range of motion of joint angles.

The Low Kneel posture was observed to be easily achieved by all participants and therefore variability of the postural dimensions is more likely to be due to systematic variation more so than factors of natural variation. Potential systematic sources of variation for all postural dimensions during data collection include: marker placement; identification of anatomical landmarks; instruction inconsistency (delivery, quality and participant interpretation). Systematic sources of variation during data analysis include: manual digitisation; non-randomisation of the order of postures.

4.2.2. **Systematic sources of variation over all the postures during data collection**

4.2.2.1. **Marker placement**

Two researchers were responsible for palpation and placement of self-adhesive and fin markers, even though it is recognised that one researcher would have had less variability on marker placement. Studies of static palpation of the spinous process of the fifth lumbar vertebrae have shown reasonable intra-tester reliability, however inter-tester reliability is generally poor (Robinson, Robinson, Bjørke, & Kvale, 2009; Russell, 1983). Therefore, having two researchers responsible for marker placement and palpation of landmarks, inconsistency may exist between sessions. The Low Kneel hip flexion angle required marker placement on the greater trochanter of the femur which has a large anatomical surface area (Schuenke, Schulte, & Schumacher, 2006) and is in a region of increased underlying subcutaneous tissue (States, 1997). The difficulty related with palpation and marker placement on anatomical landmarks and the compounded
effects of two researchers being responsible for marker placement may affect reproducibility of results. However, marker placement alone cannot entirely explain the variation of postural dimensions within this study.

Titanium dioxide was used to ensure reliable inter-session placement of markers, however the markings were often not visible at the second session. High levels of humidity during the testing sessions made application and maintenance of marker placement difficult. Adhesiveness of the tape used for the fin and self-adhesive markers was affected by humid conditions and occasionally some fin and self-adhesive markers needed to be re-secured within a session and this may add variation to the reproducibility of the postures. An air-conditioned room may have prevented this situation.

4.2.2.2. Instructions

Standardised instructions and demonstrations of the postures were given to all participants during data collection due to the participants presumed unfamiliarity with the floor sitting postures. Despite these efforts in standardisation of instruction and demonstration, postural deviations were observed. Cuing was used if the participant failed to perform the posture after the researcher repeated instructions approximately three times. Authors (Cook et al., 2006) that use similar screening tasks do not use cuing as an approach for instruction. One of the main reasons for this approach is to observe the participants natural performance of the movement pattern, without multiple and/or complicated instruction (Hoogenboom, Voight, & Cook, 2012).

Within this study, it is unclear whether deviations of posture were due to the participants failure to interpret the instructions given or if the participant interpreted the instructions correctly but were unable to perform the posture. With postural deviations observed, improving the clarity of the instructions would aid the participants understanding of performing the posture. The novelty of the floor sitting postures and using the instructions for the first time are reasons why cuing was included as an instruction method. A limitation of cuing is that the execution of the participants posture may be an unnatural response and not typical of their normal function. Further work in refining the instructions and on investigation of the influence of cuing on performance of the postures would be beneficial.
4.2.3. **Systematic sources of variation during data analysis**

4.2.3.1. **Manual digitisation**

The test-retest reliability results of the principle researcher for using manual digitisation for postural dimensions were very high. Evidence has been established for reliability of intra- and inter-session manual digitisation within a given observer (Sullivan, Bryden, & Callaghan, 2002). In the current study the reliability of manual digitisation was very high but this high reliability is not transposable to those postures that demonstrated less than acceptable reliability (Straight Leg Sit and Low Kneel). Poor visibility of small landmarks prevented accurate analysis of the postural dimensions on some photographic images, such as the dorsiflexion postural angle of the Straight Leg Sit. The postural landmark for the lateral tip of the big toe was difficult to visualise. This could have been rectified by having the video camera at a closer proximity to the participant and marking the big toe using self adhesive markers.

4.2.3.2. **Randomisation**

The six postures performed in this study were conducted in a sequence that remained the same for every trial within both the testing sessions (e.g., Squat, Squat Variation, Straight Leg Sit, Cross-legged Sit, Low Kneel, High Kneel; Squat, Squat Variation...). During data analysis of the postural dimensions, the order of postures was not randomised. Postural analysis of the dimensions for the same posture was never directly consecutive due to the sequential rotation of the postures (e.g., Session One Subject A – posture 1, 2 ...6; Session One Subject B posture 1, 2 ...6 etc.; followed by analysis of Session Two Subject A – posture 1, 2 ...6 etc.). Although not random, due to the large number of postural dimensions, it is highly unlikely that the researcher could recall prior test measurements of postural dimensions, making non-randomisation during data analysis a trivial influence on result outcomes.
4.3. Discussion of test-retest reliability results

The current study is the first to investigate floor sitting postures in a screening context and therefore results from other studies cannot be directly compared. However, inter-session reliability of screening protocols that incorporate movements instead of static posture can be compared in a broad sense. Movement based screens such as the Functional Movement Screen (Cook et al., 2006; Plisky et al., 2006) and the Star Excursion Balance Test (Plisky et al., 2006) are well developed and clinically utilised.

Complex dynamic movement patterns are considered difficult to assess and grade using only clinical judgement and visual observation, however, the developed movement based screens have demonstrated high observer-reliability between sessions, especially the Functional Movement Screen (Minick et al., 2010). The reproducibility of static posture may be higher than movement-based tasks but this has not been investigated in this study so direct comparisons cannot be made. High reliability is evident for most postural dimensions of the floor sitting postures and show sufficient promise to justify further investigation of clinical utility.

4.4. Discussion of data analysis and results generalisation

Within this study ICCs were used to determine the reliability of the postures between sessions. Sole use of ICCs to assess reliability has been questioned because it is affected by low sample heterogeneity (Ayala et al., 2011; Hopkins, 2003). Therefore, non-rigorous exclusion criteria were employed to enhance the likelihood of a heterogeneous sample. The inclusion of a wide range of ages, both genders, body morphology and ethnicity resulted in a spectrum of capabilities within the sample. The postural dimensions for four out of six postures showed narrow confidence intervals so therefore the reliability of these postural dimensions for the postures may be generalisable to populations of similar profile to the current sample.
The wide confidence intervals shown for the two postures may be an indication that those postures may be prone to higher levels of natural variability or that a larger sample size is needed to achieve greater precision. The current study did not quantify smallest detectable difference and minimal clinically important differences. Measurement error needs to be investigated in future studies so an understanding can be gained on whether changes are attributed to measurement error, verifying biological reliability, or to an introduced intervention.

4.5. Further research

Normative data is not currently available for floor sitting postures in a screening context. Normative data is necessary and should be established. Even though reliability of postural dimensions for most postures was high, the Straight Leg Sit and Low Kneel postural dimensions may need further investigation to improve reliability. Further investigation of the two postures will determine if reliability can be improved or whether the postures are not suitable for screening purposes.

The use of floor sitting postures as a screen to identify possible areas of dysfunction that may require further examination needs further field work and piloting in clinical practice. In this study, regions of discomfort and dysfunction were reported and observed while the participant performed the postures, but it is unclear if these observations of discomfort and dysfunction are clinically important. Research of the floor sitting postures is required to clarify if dysfunctional posture is a predictor of musculoskeletal pain and disability or a possible predictor of elevated risk of injury. Many clinicians relate asymmetry to pain and disability despite the absence of an evidence-based construct as to what constitutes ideal posture. Pelvic asymmetry that is commonly related to back pain has been demonstrated to not have any meaningful association (Levangie, 1999). In contrast, evidence has linked pain and disability with asymmetry of posture in the cervical spine (Yip et al., 2008). Comprehensive evidence to demonstrate the putative causal relationship between poor posture and musculoskeletal pain is lacking and may be in part due to the challenges inherent in researching this topic. Musculoskeletal pain is complex and multidimensional in nature making cause and effect relationships between pain and dysfunction challenging to research.
In order to understand if the floor sitting postures predict musculoskeletal disorders or injury, further research in the form of cross-sectional epidemiological designs might be useful. Musculoskeletal pain patients could be assessed using the floor sitting postures to discriminate different levels of disability. Future prospective research to investigate risk of musculoskeletal pain based on screening scores would also be useful. The reliability of practitioners in observing the postures using the grading criteria needs to be conducted to investigate whether the Grading Criteria can be used consistently.
CONCLUSION

In this study the postural dimensions for four out of six postures demonstrated acceptable inter-session reliability but further investigation is needed for the Straight Leg Sit and the Low Kneel postural dimensions that demonstrated less than acceptable reliability between sessions. The investigation of floor sitting postures is at a preliminary stage, but the postures that have already demonstrated reliability may have the potential to be used as a clinical screening approach in preliminary research. The developed grading criteria for the postures need further evaluation for clinical utility. Ultimately, the floor sitting postures may be used as a screening approach in clinical practice to predict injury or musculoskeletal disorders, assess treatment outcomes or direct treatment and management.
REFERENCES


References


SECTION III.

APPENDICES
APPENDIX A. ETHICS DOCUMENTATION

Ethics approval form

Bahakti Hargovan
90A Tiverton Road
New Windsor
Auckland 0600

1 March 2011

Dear Bahakti,

Your file number for this application: 2010-1136

Title: Project 1: The development of criterion for rating floor sitting postures and investigation of intra- and inter-session biological variability. Project 2: The intra- and inter-rated reliability of the developed criterion for the floor sitting postures.

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

Start date: 26 January 2011
Finish date: 25 January 2012

Please note that:
1. The above dates must be referred to on the information AND consent forms given to all participants
2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely

Lyndon Walker
Deputy Chair, UREC

cc: Matthias Houvenagel, co-investigator
Rob Moran, Osteopathy
Cynthia Almeida
Research information for participants

Investigation of floor sitting postures by development of grading criteria and test-retest reliability of posture

Please read carefully through this information sheet before you make a decision about participating.

Principal Researcher
Bhakti Hargovan and Matthias Houvenagel (Bachelor of Applied Science - Human Biology) are currently in their 1st year of the Masters of Osteopathy programme at Unitec New Zealand.

Our Purpose
This study aims to develop grading criterion and observe individual's ability to perform six floor sitting postures. This grading criteria of the floor sitting posture will enable manual therapists to screen and diagnose musculoskeletal dysfunction.

Your voluntary participation
Your participation in this study is entirely voluntary and you may withdraw at any time during the study. Data collected from your involvement in the study may be withdrawn up until 1 week following your final assessment.

Who may participate?
We are looking for adults over 18 years of age. Participants may be included in the study if they lack physical recognisable characteristics (such as tattoos), and are mobile without any external help.

Unfortunately you will not be included in the study if you have any of the following:

- Intense pain at any moment of the study
- Currently diagnosed with systemic, neurological or rheumatological diseases
- Are pregnant
- Have persistent symptoms from previous history of trauma or surgery that could be aggravated while performing the study.

What will happen in the study?
Should you agree to participate in the study, you will be required to attend two sessions.

During the first session:
• Your height and weight will be measured
• Asked to fill questionnaires which are informative of your daily physical activity
• Asked to undress into underclothing (briefs and bra) for the purpose of clear video recording while performing the six floor sitting postures
• This session’s duration is approximately 1 hour

During the second session you will be:
• Asked to re-perform the six floor sitting postures within the same conditions
• Three flexibility tests measuring angles of range of movement will be measured

The video footage will undergo pixilation of participants identifying features (face, birth marks etc.) to maintain anonymity. Finally, the video will be analysed.

What we do with the data and results, and how we protect your privacy.

Personal information is collected and stored under the guidelines provided by the Privacy Act 1993 and the Health Information Privacy Code 1994. In all instances of information collection your identity will remain anonymous and you will simply have an identification number. If the information you provide is reported or published, this will be done in a way that does not identify you as its source. All the data recorded will be stored in a password-locked computer and archived in a locked file room in the Unitec Student Osteopathic Clinic and will be stored for a minimum of 5 years. Access to this data will be limited to the principal researcher (Bhakti Hargovan and Matthias Houvenagel), the research supervisor, and yourself.

Compensation may be available in the unlikely event of injury of negligence

Should you incur a physical injury as a result of your participation in this study, you may be covered by ACC under the Injury Prevention, Rehabilitation and Compensation Act 2002. You may or may not be entitled to ACC compensation, depending on several factors such as whether or not you are an earner. ACC will usually cover a proportion of income lost due to a physical injury, this does not cover mental injury unless as a direct result from a physical injury. ACC cover may affect your right to sue. Please contact your nearest ACC office for further information (0800 735 566) or visit their website: www.acc.co.nz

Please contact us if you need further information about the study.

Contact Details:

Bhakti Hargovan  
Phone: 021 1730328  
Email: bhargovan@gmail.com

Matthias Houvenagel  
Phone: 021 1578278  
Email: matthiaishou@yahoo.fr

UREC REGISTRATION NUMBER: (2010-1136)

This study has been approved by the UNITEC Research Ethics Committee. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Participant consent form

Investigation of floor sitting postures by development grading criteria and test-retest reliability

This form is to ensure that you understand the requirements of your participation and that you are aware of your rights. Please read carefully through the points below. If you are happy and agree with the points then please sign at the bottom of the page. If you have any questions at all please ask the researcher before signing this form.

I have had the research project explained to me and I have read and understood the information sheet given to me.

I understand that I don't have to be part of this if I don't want to and I may withdraw at any time prior to the completion of the research project.

I understand that everything I say and the information I provide will be collected in accordance with the Health Information Privacy Code 1994 and kept confidential and in accordance with the Privacy Act 1993. I understand that the only persons who will have access to my information will be the researcher and relevant clinical staff.

I understand that all the information I give will be stored securely on a computer at Unitec for a period of 5 years.

I understand that I can see the finished research document.

I have had time to consider the information provided, to ask questions, and to seek any guidance.

I give my consent to be a part of this project

Participant Signature: .............................. Date: ..............................

Principle Researcher: .............................. Date: ..............................

UREC REGISTRATION NUMBER: (2010-1136)

This study has been approved by the UNITEC Research Ethics Committee. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Participant profile form

Name: ________________________________________________________________________________________

Date of Birth: __/__/_____

Age: ____

Male ☐ Female ☐

Ethnicity: ______________________________________________________________________________________

Occupation: ______________________________________________________________________________________

Address: ________________________________________________________________________________________

Suburb: _________________________________________________________________________________________

Ph: (H) __________________ (Mob) __________________ (Email)

MEDICAL HISTORY QUESTIONS:

Do you have any rheumatologic condition? ☐ ☐

Do you have any malignant conditions? ☐ ☐

Are you pregnant? ☐ ☐

Are you being treated by any manipulative or bodywork therapist? ☐ ☐

ANY PAIN OR INJURIES TO:

Back: ___________________________________ Neck: ______________________________

Knees: ______________________________ Ankle: ______________________________

Hips __________________________________ Shoulder: _____________________________

How severe is your pain? Circle the number below that corresponds to your pain level.

Little to no pain 1 2 3 4 5 6 7 8 9 10 Severe pain

ACTIVITY LEVEL

What is your activity level a day (in minutes or hours)? _________________________________________

What is the activity? _________________________________________________________________________

How many hours of sitting done a day (in minutes or hours)? _________________________________

STATEMENT:

I understand that requirements of this research project and that I can withdraw at any time. I have answered the questions to the best of my ability and understand that for research purposed this profile form and information will be withheld by the researcher.

Signature: ______________________________ Date: __/__/_____

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## APPENDIX B. DESCRIPTORS FOR POSTURAL DIMENSIONS

<table>
<thead>
<tr>
<th>Variables</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Coefficient of Variation (CV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Squat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion of ankle</td>
<td>24.33</td>
<td>45.33</td>
<td>69.67</td>
<td>61.43</td>
<td>5.94</td>
<td>9.67</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>104.00</td>
<td>31.00</td>
<td>135.00</td>
<td>77.19</td>
<td>32.68</td>
<td>42.34</td>
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<tr>
<td>Hip flexion</td>
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<td>62.67</td>
<td>119.67</td>
<td>85.22</td>
<td>12.70</td>
<td>14.90</td>
</tr>
<tr>
<td>Lumbar angle</td>
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<td>-4.33</td>
<td>-31.03</td>
<td>17.82</td>
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<tr>
<td>Distance between knees</td>
<td>38.03</td>
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<td>38.33</td>
<td>24.79</td>
<td>8.04</td>
<td>32.43</td>
</tr>
<tr>
<td>Distance between ankles</td>
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<td>24.00</td>
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APPENDIX C. AUTHORS GUIDE FOR JOURNAL OF BODYWORK AND MOVEMENT THERAPIES

Further guidelines can be found at: http://www.bodyworkmovementtherapies.com/authorinfo

Official journal of the:
- Association of Neuromuscular Therapists
- Australian Pilates Method Association
- National Association of Myofascial Trigger Point Therapists, USA

Now indexed in Medline

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If unable to submit your manuscript via email then the submission of a disk along with your typescript is accepted. The Editor will accept a 3.5 inch disk in any IBM or Macintosh word processing format (Microsoft Word 2001 is preferred). Please indicate on the label attached to your disk, your name, address, typescript title and the name of the word processing package used.

WORD COUNT
We can accept full articles of between 2000 and 4000 words in length. Shorter reports and items will comprise fewer words. Please check your ideal length with the journal Editor.

PRESENTATION OF TYPESCRIPTS
Your article should be typed on one side of the paper, double spaced with a margin of at least 3cm. Rejected articles, and disks, will not be returned to the author unless an SAE is enclosed.

Papers should be set out as follows, with each section beginning on a separate sheet: title page, abstract, text, acknowledgements, references, tables, and captions to illustrations.

Title Page: The title page should give the following information:

APPENDICES
Appendices

*title of the article*
*full name of each author*
*you should give a maximum of four degrees/qualifications for each author and the current relevant appointment*
*name and address of the department or institution to which the work should be attributed*
*name, address, telephone and fax numbers of the author responsible for correspondence and to whom requests for reprints should be sent.*

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**Abstract:** This should consist of **100-150 words summarising** the content of the article.

**Text:** **Headings** should be appropriate to the nature of the paper. The use of headings enhances readability. Three categories of headings should be used:
- major ones should be typed in capital letters in the centre of the page and underlined
- secondary ones should be typed in lower case (with an initial capital letter) in the left hand margin and underlined
- minor ones typed in lower case and italicised

- Do not use 'he', 'his', etc. where the sex of the person is unknown; say 'the patient', etc. Avoid inelegant alternatives such as 'he/she'. Avoid sexist language.
- Avoid the use of first person ('I' statements) and second person ('you' statements). Third person, objective reporting is appropriate. In the case of reporting an opinion statement or one that cannot be referenced, the rare use of 'In the author's opinion?' or 'In the author's experience?' might be appropriate. If in doubt, ask the editor or associate editor for assistance.
- Acronyms used within the text are spelled out at the first location of usage and used as the acronym thereafter. For example, 'The location of a central trigger point (CTrP) is central to a taut fiber. The CTrP is palpated by.......

- Single quotation marks are used to express a quote marks (Matthews (1989) suggests, 'The best type of?') while double quotation marks are used for a quote within a quote or to emphasise a word within a quote.
- Promotion of self, seminars or products is inappropriate. Reference to a particular product as it applies to the discussion, particularly where valid research of the product or comparison of products is concerned, can be included as long as a non-promotional manner is used.

**References:** The accuracy of references is the responsibility of the author. This includes not only the correct contextual use of the material, but also the citation itself. In the text your reference should state the author's surname and the year of publication (Smith 1989); if there are two authors you should give both surnames (Smith & Black 1989). When a source has more than two authors, give the name of the first author followed by 'et al'. (Smith et al 1989). No commas are used between the name and date. It is important to verify the correct and full title, the full authorship, and all other reference details with the original source (book, journal, etc.,) or through a service, such as Medline or ScienceDirect.

A list of all references in your manuscript should be typed in alphabetical order, double spaced on a separate sheet of paper. Each reference to a paper needs to include the author’s surname and initials, year of publication, full title of the paper, full name of the journal, volume number and first and last page numbers. The names of multiple authors are separated by a comma with each appearing as surname followed by initials. The date is placed after the author’s name(s), not at the end of the citation.

Here are examples:


References to books should be in a slightly different form:
Hicks CM 1995 Research for Physiotherapists. Churchill Livingstone, Edinburgh
When citing a paper that has a digital object identifier (doi) please use the following style:

**Tables:** These should be double spaced on separate sheets and contain only horizontal lines. Do not submit tables as photographs. A short descriptive title should appear above each table and any footnotes suitably identified below. Ensure that each table is cited in the text.