ESTABLISHING ASSOCIATIONS FOR THE EVALUATION OF MOBILITY SCREEN (EMS) IN AN ADULT SOUTH AFRICAN POPULATION

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DECLARATION

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Marthinus Lotz Brink

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GLOSSARY OF TERMS

Functional Screening: The assessment of strength, symmetry and flexibility to identify deficiencies

Musculoskeletal injury: Any injury to the human body that involves soft tissue such as muscle, ligament, tendon or cartilage

Neuromuscular control: The subconscious response of a muscle to maintain balance and stability of the body, also known as proprioception

Dynamic joint stability: The ability of the body to maintain stability through movement

LIST OF ABBREVIATIONS

ADL	Activities of Daily Living
BMI	Body Mass Index
EMS	Evaluation of Movement Screen
FMS	Functional Movement Screen
GPAQ	Global Physical Activity Questionnaire
HPAPQ	Healthy Physical Activity Participation Questionnaire
ICC	The Intra Class Coefficient
IQR	Interquartile Range
LR	Likelihood ratio
METS	Self-Reported Metabolic Equivalent
Q-Coh	Quality of Cohort Studies
SSISA	Sports Science Institute of South Africa
TRIPP	Translating Research into Injury Prevention Practice

ABSTRACT

Background: Muscle, joint and bone injuries affect mobility and stability, which in turn limits physical activity. Screening tests such as the Functional Movement Screen (FMS) are used to assess an individual's mobility and stability to determine whether any movement dysfunctions exist. Screening tests aim to establish an individual's injury risk with the goal of guiding an intervention program. The Evaluation of Mobility Screen (EMS) is a screening test that has been developed at the Sports Science Institute of South Africa. The EMS has been adapted from the FMS by exchanging the Rotatory Stability test for the Seated Rotation test. The current use of screening tools is limited because of the lack of normative data sets that represent the diversity of age, gender and physical activity levels in the general population. Most current published data represent athletes or younger populations. By establishing the relationship between screening outcomes and variables such as age, gender and physical activity level, the effectiveness of screening tests may be improved.

Aim: To describe associations between EMS scores for males and females across different age groups and levels of physical activity.

Objective: To evaluate and compare differences in EMS scores relating to age, gender and physical activity levels.

Methods: This was a quantitative study, with a descriptive, correlational design. The sample consisted of 135 males and 127 females between the ages of 18 and 60. The EMS data were collected at the High-Performance Centre, in the Sports Science Institute of South Africa, Cape Town.

Results: There was no difference between the total scores of males and females (median = 17). The two youngest groups (20-30 and 31-40 years) scored the highest (median = 17), while the oldest group (51-60 years) scored the lowest (median = 15). Gender had a significant effect ($p < 0.05$) on five subtests (Single Leg Hurdle, Shoulder Mobility, Asymmetric Leg Raise, Stability Push Up and Seated Rotation). Age had a significant effect ($p < 0.05$) on three subtests (Overhead Squat, Single Leg, Hurdle Split Squat). Physical activity level had a significant effect ($p < 0.05$) with two subtests (Single leg Hurdle and Stability Push Up).

Conclusion: Gender, Age and Physical Activity are associated with changes in EMS scores. EMS total scores declined as age increased. While the total scores remain similar between genders, there were clear variations within the different subtests. The oldest participants (51-60 year) scored the lowest throughout all subtests. Males scored higher in the strength components, while females scored higher in the flexibility components. Physical activity levels did not have a clear pattern as expected but still demonstrated association with two subtests. The results add to the sentiment that the focus should move away from the composite scoring system, and towards analyzing individual subtest scores. Future studies should also investigate if subtest scores can be improved by targeted intervention programs.

Key words: *“injury prevention”, “injury risk assessment”, “injury screening”, “preparticipation screening”, “Functional Movement Screen (FMS)”, “reference values”, “normative values”*.

CHAPTER ONE

INTRODUCTION AND SCOPE OF THESIS

INTRODUCTION

Injury prevention is an emerging field in medicine, with growing interest from many areas (van Dyk & Clarsen, 2017). The main aim of this field is to decrease injury incidence and therefore allow individuals to participate in physical activity without limitations. Through understanding injury aetiology, risk factors and mechanisms of injury, preventative measures may be developed.

Increased activity levels have many beneficial health effects ranging from decreased risk of chronic diseases, increased mobility and improved musculoskeletal health (Baudry, 2016; Nunan, Mahtani, Roberts, & Heneghan, 2013; Zampieri et al., 2015). In the general population, there is a high incidence of musculoskeletal injuries in active and non-active individuals (Hootman et al., 2002). These injuries may result in a long time-loss from activity participation and may also prevent return to work in severe cases. Furthermore, musculoskeletal injuries can also be an economic burden (Mock & Cherian, 2008). Injuries result in high medical expenses for national health systems and medical aid schemes (Brooks, 2006; Hoy et al., 2014). By preventing injuries people will be able to live more active lifestyles and medical expenses could be decreased (Hoy et al., 2014).

Injury prevention has gained considerable interest from sports medicine, because a healthy, uninjured athlete can perform at a higher level. Sport has challenged the injury prevention field to find fast and accurate ways to establish risk factors and prevent injuries (Wright et al., 2016). Screening tests have been developed to identify risk factors that may lead to injury (McCall et al., 2015). There is currently no consensus on which screening test works best. There has been a tendency in the literature to favour functional testing (Chimera & Warren, 2016; Kiesel et al., 2013). Functional testing involves the evaluation of symmetry, stability and control of movement. It has been proposed that insufficiency of these factors, may place the body under undesirable stress that may lead to injury (Beckham, 2010; Cook, Burton, Hoogenboom, & Voight, 2014).

The Evaluation of Mobility Screen (EMS) used in this study is a screening test that has been developed at the Sports Science Institute of South Africa (SSISA). The EMS has been adapted from the Functional Movement Screen (FMS) (Cook et al., 2014) by exchanging the Rotatory Stability test for the Seated Rotation test. The FMS is one of the functional screening tests that has grown rapidly since its inception and is now widely used in sports (Wright et al., 2016). The main reasons for the popularity of the FMS is that it is relatively simple, inexpensive and time efficient. Recently, there has been interest to use the FMS in the general population (Koehle, Saffer, Sinnen, & MacInnis, 2016). Although the FMS has shown potential to serve as a general screening test, many factors relating to its use are still unclear.

Most of the available research on normative data has been conducted in young active populations. The use of these homogenous samples has limited the interpretation of these results to a broader population (Mitchell, Johnson, Vehrs, Feland, & Hilton, 2016). It is unclear how factors such as age, gender and physical activity influences scoring in functional screening, as there is only limited research on functional screening scores in the general population.

Therefore, the aim of this dissertation was to describe associations of different variables such as age, gender and physical activity with functional screening using the EMS protocol. The findings could provide reference values to make the EMS a more relevant screening tool for adults across different age groups and physical activity levels.

This thesis consists of four chapters. A comprehensive review of the literature will be presented in the next chapter (Chapter 2). This will be followed by a study designed to answer the above question (Chapter 3). This chapter has been styled to represent a scientific paper and includes an introduction, methods, results and discussion section. The final chapter will summarise, contextualise and translate the findings of the dissertation (Chapter 4).

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The benefits associated with physical activity are well known (Blair, 2009). These benefits range from increased muscle mass, bone density, cardiovascular fitness and cognitive function (Armstrong, Tomkinson, & Ekelund, 2011; Gutin et al., 2002). Exercise has been shown to slow the normal age associated decreases in strength and bone mass usually caused by sarcopenia and osteoporosis respectively (Bolam, van Uffelen, & Taaffe, 2013; Landi, Marzetti, Martone, Bernabei, & Onder, 2014). Increased physical activity may also improve balance and prevent the risk of falling in older individuals (El-Khoury, Cassou, Charles, & Dargent-Molina, 2013). There is undeniable evidence that increased physical activity levels decreases the risk of chronic diseases such as diabetes and heart disease (Daley & Spinks, 2000).

However, increased physical activity also leads to an increased risk of injury. Musculoskeletal injuries have been found to be the main reason for temporary and permanent cessation from activity participation (Hootman et al., 2002). Up to 20% of all acute injuries treated in hospitals of developed countries are caused by sports and physical activity (Engebretsen et al., 2012). This has driven researchers to find possible ways of reducing and preventing injuries. The insufficiency of symmetry, flexibility and strength has been strongly linked to the development musculoskeletal injury (Beckham, 2010). A lack of these components may alter movement patterns, which are essential for performing activities safely and efficiently (Cook et al., 2014). Therefore, screening tests were developed to evaluate the risk of potential injury. Assessing certain functional movements could provide an opportunity to correct and improve specific areas of insufficiency (Cook et al., 2014). This could lead to reducing the risk of getting an injury (Kiesel, Plisky, & Voight, 2007; Yeung, Cleves, Griffiths, & Nokes, 2016). The Functional Movement Screen (FMS) is currently the most widely used screening test. It was developed to assess an individual's weaknesses that might predispose them to injury (Cook et al., 2014). The Evaluation of Mobility Screen (EMS) is a screening tool that was developed at the High-Performance Centre at the Sports Science Institute of South Africa (SSISA). The EMS was adapted from the FMS by changing one of the subtests used to assess trunk mobility and stability. However, the composite scoring system of the EMS remains the same as the FMS.

The review will firstly define injury prevention and outline the different prevention strategies that are currently available. The focus then shifts to describe the current uses and limitations of functional movement screening. Finally, the review will identify how further research may improve the application of the FMS and, by implication, the EMS.

Data were sourced from sports medicine and science literature utilising searches on PubMed, Web of Science, Medline and Google Scholar.

Keywords used in the search included *"injury prevention", "injury risk", "injury screening", "preparticipation screening", "Functional Movement Screen (FMS)", "reference values" and "normative values".*

2.2 INJURY PREVENTION

Injury prevention is a subfield in medicine focusing on strategies to decrease the incidence of sporting injuries. Research in this field aims to establish relationships between potential risk factors and injuries (Howe, Waldron, & Read, 2017; Van Mechelen, Hlobil, & Kemper, 1992). The field of injury prevention has attracted substantial interest in the past decade. Epidemiological studies show that sporting injuries rate amongst the highest of all treated injuries in emergency departments (Bahr & Engebretsen, 2011). Sporting injuries could lead to a time loss from participation in sport, ranging from days to months. Severe injuries can also lead to a loss of working time. Severe injuries are associated with large medical costs, which could burden the individual and national health systems (Orchard, 2008).

Preventing injuries is a multi-factorial process. It has been proposed by Finch (2006), that a new TRIPP (Translating Research into Injury Prevention Practice) research model is required, compared to the previous 4-step model of van Mechelen et al. (1992) (Figure 2.1). The TRIPP model recognizes the shortfall of research that establishes causality between injuries and risk factors. Effective prevention strategies can only be developed once clear aetiology have been established (Bahr & Krosshaug, 2005).

Stage	**TRIPP MODEL** (Finch, 2006)	**4 Stage Model** (Van Mechelen et al., 1992)
1	Injury surveillance	Establish extent of problem
2	Establish aetiology and mechanisms of injury	Establish aetiology and mechanisms of injury
3	Develop preventative measures	Introduce preventative measures
4	Scientific evaluation	Assess effectiveness by repeating stage 1
5	Describe intervention context to inform implementation strategies	
6	Evaluate effectiveness of preventative measures in implementation context	

Figure 2.1 Stages of Injury Prevention

The development of a prevention strategy requires a multi-disciplinary approach. Theoretical knowledge of the mechanism of injury and underlying risk factors forms the basis of this approach. By understanding and identifying risk factors, clinicians can develop strategies to eliminate potential problems before they happen (Bahr & Krosshaug, 2005; Cook et al., 2014). The notion that underlying problems can be corrected, has led to great interest in screening tools. These tools aim to evaluate an individual's risk of developing injuries. Most of functional screening tools consist of a series of tests that focus on evaluating an individual's range of movement, control and balance (Bakken, Targett, Bere, Eirale, et al., 2016; Cook et al., 2014; McCall et al., 2015; McCunn et al., 2017). Once identified, it is proposed that the individual can work actively with a skilled clinician to negate these deficiencies. It is assumed that this will decrease the risk of injury.

However, this type of injury screening tool has recently been scrutinized by prominent researchers in the field (Bahr, 2016; Wright et al., 2016). In a recent review, Bahr (2016) suggested that many of these tools are unable to predict injury risk as they lack specificity and sensitivity. He also states that one should be careful to interpret screening tests results, as many do not take unmodifiable factors such as age and gender into account. There has been a sharp response to the claims, stating that Bahr has previously used the same methods that he is now criticizing (Hewett, 2016). The main problem is that no test has shown a high degree of sensitivity to deserve the label of "screening". The title "Screening Test", implies that the test can identify a problem through early detection with a high level of accuracy (Bahr, 2016; van Dyk & Clarsen, 2017; Wright et al., 2016). This is currently not the case as these tests show low levels of sensitivity (Bakken, Targett, Bere, Adamuz, et al., 2016; B. S. Dorrel, Long, Shaffer, & Myer, 2015; Moran, Schneiders, Mason, & Sullivan, 2017).

This debate comes at an interesting time as conflicting evidence is emerging on the use of these specific screening tests. A recent meta-analysis by Bonazza et al., (2016) found evidence to confirm the injury predictive capabilities for the FMS, which should add to the credibility of its use. However, many of the studies Bonazza et al., (2016) reviewed used small homogenous samples. This limits the interpretation of the scoring, as outcomes may only apply to the specific studied populations (Wright et al., 2016). Contrary to these findings, more recent evidence has discredited the capability of composite scoring tests to predict injury (Bakken et al., 2017; Moran et al., 2017). The most recent meta-analysis by Moran et al., (2017) is highly critical on the poor methodology used by Bonazza et al (2016).

Interpretation of findings are challenging as methodology differs greatly among studies (Moran et al., 2017). Most studies used homogenous groups of participants of the same gender and age groups. Many studies have also limited their participants to single sports, which makes translation of the findings to other populations difficult. Only three studies have used participants from the general population opposed to sports groups (Koehle et al., 2016; Mitchell et al., 2016; Perry & Koehle, 2013). Therefore, it is currently inappropriate to use the screening tool as an outcome measure for sedentary or low physical activity groups. Further research should use larger and more heterogeneous populations. The relationship between screening scores and unmodifiable factors such as age and gender is still unclear as many studies have used relatively young populations (Roald Bahr, 2016; Moran, Schneiders, Major, & Sullivan, 2015).

While the application and interpretation of the test scores are the cause of much debate, the value of the individual tests should not be underestimated (Bahr, 2016; Hewett, 2016; Wright et al., 2016). Regardless of the prediction capabilities, screening tests may still aid in identifying certain functional deficits which could lead to injury (Bakken et al., 2017; Bonazza et al., 2016; B. S. Dorrel et al., 2015). Screening tests also help to build clinician and patient relationships (van Dyk & Clarsen, 2017; Wright et al., 2016). To improve the clinical use of these screening tests it is important to develop an understanding of the normative values and how factors such as age, gender and physical activity levels could influence test findings.

Summary of the Literature: Injury Prevention

There is currently no consensus on the effectiveness of injury screening tools. An ongoing debate exists about the ability of screening tools to predict injury. However, there is evidence to suggest these tests can identify weaknesses and imbalances. It also provides an opportunity for the patient and clinician to interact. Almost all studies have used small homogenous sample sizes, which makes interpretation of results difficult. To fully understand the outcomes of injury predicting tests, it is important to understand the co-existing factors that may influence scores.

2.3 MUSCULOSKELETAL INJURY AND RISK FACTORS

The incidence of musculoskeletal injury among the general population has been reported to be as high as 40%. Approximately 80% of these injuries may be activity related and 70% may lead to temporary cessation of exercise (Almeida, Williams, Shaffer, & Brodine, 1999; Hootman et al., 2002). This evidence shows that musculoskeletal injuries have a negative impact on physical activity levels.

Musculoskeletal injuries are described as any injury to the human body that involves soft tissue such as muscle, ligament, tendon, cartilage or bone (Engebretsen et al., 2012). These injuries are subclassified into acute and overuse categories. Acute injuries are often caused by a sudden incident that may involve an external force. Overuse injuries have a more gradual onset. Acute injuries tend to happen more often during sporting activities which involve high speed and contact such as football, rugby and ice hockey. Overuse injuries are usually a result of repetitive loading, which is more common in aerobic sports such as running, swimming and cycling (Engebretsen et al., 2012). The definition for injury has not been consistent in the literature, making the interpretation and comparison between studies difficult (Flint, Wade, Giuliani, & Rue, 2014).

Although several studies have attempted to explain the causative factors of injuries, there is no consistent explanation. This is because musculoskeletal injuries are caused by an interaction of multiple factors (Bahr & Krosshaug, 2005). These factors can be divided into extrinsic and intrinsic risk factors. Extrinsic risk factors are usually described as modifiable or independent factors, which is not directly related to the condition of the individual (e.g. terrain, weather, equipment etc.). Intrinsic risk factors relate to all components directly relatable to the condition of the individual (e.g. flexibility, strength, age, gender etc.) (Bahr & Engebretsen, 2011). Intrinsic factors can also be described as unmodifiable or dependent risk factors.

For this literature review, the focus will be on describing intrinsic risk factors which may influence screening outcomes. Many other risk factors exist, but these remain outside the scope of this review.

2.2.1 Flexibility and Range of motion

Flexibility has long been advocated as an important part of the healthy athlete paradigm. Decreased muscle flexibility has been linked to higher rates of injuries (Bradley & Portas, 2007; Witvrouw, Danneels, Asselman, D'Have, & Cambier, 2003). Until recently it was accepted that increased flexibility is associated with a decreased risk of injury. The theory behind this was that increased muscle compliance would place the muscle tendon unit under less strain and decrease the internal forces subjected onto the body (Witvrouw et al., 2003). However, a recent meta-analysis has questioned this association (Freckleton & Pizzari, 2013).

Biomechanical analysis has linked increased flexibility and joint hyperlaxity to decreased joint stability, which may increase risk of joint injuries (Myer, Ford, Paterno, Nick, & Hewett, 2008; Rozzi, Lephart, Gear, & Fu, 1999). Also, there is evidence that stiffer muscle tendon units have increased mechanical efficiency which may improve performance and lower the risk of overuse injuries (Ettema, 2001). This might be beneficial for sports involving low loading rates and high repetitions. Conversely, increased flexibility might reduce muscle injury in sports which involve high force generation (Witvrouw, Mahieu, & McNair, 2011).

Many questions regarding the relationship between flexibility and injury prevention remain. Current evidence is conflicting at best. In a review, Witvrouw et al., (2011) proposed that increasing muscle flexibility above the functional demands of the sport, could increase injury risk. In accordance with this finding an athlete's individual needs should be carefully considered when assessing for deficiencies. Further research can aid in understanding how these factors contribute to functional movement.

2.2.2 Strength and Neuromuscular Control

Strength and neuromuscular control are important for stabilizing the body and decreasing abnormal loads. Failure to do so may lead to injury (Decker, Torry, Wyland, Sterett, & Steadman, 2003; Emery, Roy, Whittaker, Nettel-Aguirre, & Van Mechelen, 2015; Faigenbaum et al., 2009; Peate, Bates, Lunda, Francis, & Bellamy, 2007; Whittaker, Small, Maffey, & Emery, 2015; Witchalls, Blanch, Waddington, & Adams, 2012). Recent literature shows that neuromuscular and strength training can decrease incidence of the lower limbs injuries (Donnell-Fink et al., 2015; Grimm, Jacobs Jr, Kim, Denney, & Shea, 2015; Michaelidis & Koumantakis, 2014; Myer, Sugimoto, Thomas, & Hewett, 2013; Verhagen & Bay, 2010). It is currently difficult to establish which component (strength or neuromuscular control) is more important as most prevention strategies contain a combination of strength and neuromuscular training (Donnell-Fink et al., 2015; Verhagen & Bay, 2010).

Improvement in core strength has been directly linked to decreasing lower back (Chang, Lin, & Lai, 2015; Peate et al., 2007) and lower limb injuries (Hewett & Myer, 2005; Whittaker et al., 2015; Willson, Dougherty, Ireland, & Davis, 2005; Witchalls et al., 2012). Strength asymmetry between limbs has been identified as a high predictor of injuries regardless of peak strength (Freckleton & Pizzari, 2013; Fuller et al., 2017; Mokha, Sprague, & Gatens, 2016). This suggests that strength symmetry between limbs and muscle balance may be more important than previously thought (Mokha et al., 2016). This makes muscle symmetry, and not only strength, an important factor to consider in screening tests.

There is a relative lack of evidence on risk factors for upper limb injuries, and no current consensus exists(Cools, Johansson, Borms, & Maenhout, 2015). It was previously believed that rotator cuff strength and scapular dyskinesis were important risk factors in shoulder injuries (Bahr & Krosshaug, 2005). Strength deficits of the external rotators, poor scapular control and decreased range of motion have been linked to increased injury risk (Cools et al., 2015). Although more recent research would suggest that these factors may be accepted as normal variability (Plummer, Sum, Pozzi, Varghese, & Michener, 2017). Evidence relating to upper extremity injury prevention is relatively weak and current knowledge is still conflicting.

In summary, there is moderate to good evidence that strength and neuromuscular control are key factors for reducing injury risk. Symmetry between limbs should also be considered as it has shown to be a predictor of lower limb injuries (Freckleton & Pizzari, 2013). It is therefore essential that these factors are incorporated into functional screening tests.

2.2.3 Age

Ageing is strongly linked to the natural process of physical deterioration (Daley & Spinks, 2000; Landi et al., 2014). This has an impact on many different structures in the human body. Strength, flexibility and balance are some of the most important physical attributes affected by ageing (Baudry, 2016; Holland, Tanaka, Shigematsu, & Nakagaichi, 2002).

Strength loss is attributed to sarcopenia, which is the general loss of muscle mass with increasing age (Landi et al., 2014). Muscle strength is closely related to mobility, functional ability and physical fitness levels (Trombetti et al., 2016). Maintaining muscle strength is an integral part of having higher levels of function at older age (Brill, Macera, Davis, Blair, & Gordon, 2000; Holland et al., 2002; Zampieri et al., 2015). Loss of strength in older adults is directly linked with an increased potential of suffering injuries caused by weakness, fatigue and poor balance (Warburton, Nicol, & Bredin, 2006). Both men and women show peak strength levels between 20-40 years after which a plateau is reached. Thereafter peak strength decreases with 25% by the age of 65 (Daley & Spinks, 2000; Lindle et al., 1997).

Older age brings many physical changes to the human body. As humans grow older ligaments and tendons stiffen, as cross linkages form between connective tissue fibres. Cartilage and spinal disc structures also degenerates and loses its ability to absorb shock (Daly et al., 2013; Galbusera et al., 2014; Landi et al., 2014; Wall, Dirks, & van Loon, 2013). This leads to considerable loss of flexibility and joint range of motion as elastic properties diminish. Joints of the lower extremities have shown range of motion decreases up to 58% in the elderly (Soucie et al., 2011). Lumbar spine range of motion decreases by 25-50% between

25-65 years (Daley & Spinks, 2000; Galbusera et al., 2014). As flexibility decreases, individuals become more inclined to use compensatory movements to achieve tasks (Holland et al., 2002).

Bone mass decline is another key factor associated with ageing. Bone reabsorption and redisposition rates decreases significantly with ageing (Bailey, Faulkner, & McKay, 1996; Daly et al., 2013). This makes osteoporosis a concern for the ageing individual. Calcium losses may start as early as 30 years and generally accelerates from 40 years onwards (Bailey et al., 1996). At 60 years bone density decreases of 30-50% have been noted. The decrease in bone density can progress to stages where bone becomes so weak that even minor falls can cause serious fractures (Bolam et al., 2013; Daly et al., 2013)

Although research has shown that older age is associated with decreases in balance and coordination, the underlying factors are not thoroughly understood (Shaffer & Harrison, 2007). A range of degenerative morphological changes are seen in spinal cord nerves of older individuals (Baudry, 2016). These changes are proposed to decrease motor control and proprioception which will lead to decreased balance (Baudry, 2016; Konrad, Girardi, & Helfert, 1999). Although poor balance is often associated with older individuals, no significant differences are reported among active adults younger than 65 years (Shaffer & Harrison, 2007). Decreases in balance are more prevalent in sedentary populations and adults above 70 years (Nakano, Otonari, Takara, Carmo, & Tanaka, 2014). This suggests that balance may be preserved in individuals who participate in regular exercise.

Although older age is a risk factor for injury, exercise can reduce the risk of injury associated with increasing age (Bolam et al., 2013; El-Khoury et al., 2013; Landi et al., 2014). The literature strongly advocates exercise as means of slowing the natural effects of ageing. Specific exercise regimens have shown to improve muscle mass, flexibility, bone density and neuromuscular control in the older population (Daley & Spinks, 2000). When assessing individuals with functional screening tools, it is important to consider the multitude of factors which might affect their performance. The normative values for older individuals will be different to the normative values of younger people as strength, flexibility and control plays an integral role during these tests.

2.2.4 Gender

Studies have reported that females have three to eight times higher risk of suffering an injury, during activity, compared to males (Doherty et al., 2014; Prodromos, Han, Rogowski, Joyce, & Shi, 2007; Warburton, Gledhill, & Quinney, 2001). Additionally, younger active females have an even higher risk compared to their older counterparts (Hootman et al., 2002).

The factors leading to higher injury rates in females, are not fully understood. However, underlying factors may be explained by physical differences in skeletal structure, joint laxity and muscle characteristics amongst different genders (Prodromos et al., 2007; Ristolainen, Heinonen, Waller, Kujala, & Kettunen, 2009). These differences affect flexibility, stability and joint kinematics (Blackburn, Bell, Norcross, Hudson, & Kimsey, 2009; Decker et al., 2003; Granata, Wilson, & Padua, 2002; Kubo, Kanehisa, & Fukunaga, 2003; l'Allemand-Jander, 2010). All these factors are integral components of functional movement.

It is widely accepted that females have higher levels of flexibility and joint range of motion than males. Females have higher levels of range of motion at the spine (Intolo et al., 2009) and the extremities (Chung, Choi, & Shin, 1990). The increased ROM has been attributed to decreased ligamentous and muscle stiffness (Granata, Wilson, & Padua, 2002). Females have only 57-73% of muscle stiffness in the lower limb compared to men (Granata, Padua, & Wilson, 2002). Stability around female joints are markedly decreased, which lowers their shock absorbing potential (Witchalls et al., 2012; Zazulak et al., 2005). These features are especially important during physical activity that involves jumping and directional changes. Activities such as these expose joints to high loading forces, which may cause failure if the force is not absorbed effectively (Decker et al., 2003)

Muscle strength varies between genders (Lindle et al., 1997; Myer et al., 2013; Stoll, Huber, Seifert, Michel, & Stucki, 2000). Males possess greater strength in the upper and lower body compared to equally trained females. This is true in absolute terms and after adjustments for differences in fat free mass (Lindle et al., 1997). As females have lower levels of strength, it has been suggested that they would use altered mechanics compared to men (Decker et al., 2003; Pollard, Sigward, & Powers, 2007). Kinematic studies show that females use movement strategies that places their joints under higher risk of sustaining lower limb injuries (Hewett, Ford, Myer, Wanstrath, & Scheper, 2006; Imwalle, Myer, Ford, & Hewett, 2009; Zazulak et al., 2005). These adaptations to movement have been linked to decreased core stability (Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007), hip muscle activation (Zazulak et al., 2005) and proprioception (Rozzi et al., 1999).

There is moderate evidence that gender may contribute to an individual's injury risk. Although the factors are not clearly understood, evidence shows that males have higher levels of strength and control while females are more flexible. Since flexibility and control are key components of the screening tests, it may be assumed that test scores will differ between genders.

2.2.5 Physical Activity

Increased levels of physical activity are associated with numerous health benefits. Overwhelming evidence exists to show that physical activity is an effective preventative measure for several chronic diseases (Lee et al., 2012; Nunan et al., 2013; Warburton et al., 2006). Increased levels of physical activity also maintain and improve musculoskeletal health, which in turn improves functional ability (Legrand et al., 2014). Although physical activity may be related to a higher prevalence of musculoskeletal injury (Hootman et al., 2002), the benefits far outweigh the negative consequences. Evidence on the relationship of strength and flexibility to physical activity will be discussed in the following paragraphs.

Physical activity has many positive effects on muscle characteristics. According to the New Canadian Physical Activity Guidelines, (Tremblay et al., 2011) 150-300 minutes of vigorous aerobic activity and two days of strength training a week, is sufficient to have positive health benefits in adults. The American College of Sports Medicine recommends that healthy adults between 18 to 65 years should complete at least 30 minutes of moderate-intensity aerobic physical activity, five days per week. This may be alternated with vigorous-intensity aerobic physical activity for a minimum of 20 minutes, three days per week (Lazzer, Rejc, & Del Torto, 2018; Nelson et al., 2007). Programs involving resistance training are effective in improving muscle strength and power (Harries, Lubans, & Callister, 2015). Strength training also delays the onset of sarcopenia related to the normal ageing process (Landi et al., 2014; Montero-Fernandez & Serra-Rexach, 2013). In contrast, sedentary lifestyles have been linked to early onset muscle atrophy which leads to decreased strength and function (Zampieri et al., 2015). Hence increased physical activity allows individuals to remain stronger and fitter for longer. This will allow individuals to maintain a higher functional level and continue living an active lifestyle (Daley & Spinks, 2000; Zampieri et al., 2015).

The relationship between flexibility and physical activity levels is more difficult to postulate. During periods of immobilization there is an increase in connective tissue between muscle fibres, which increases stiffness, and my decrease mobility (Wall et al., 2013). However, stretching programs of twenty minutes a day over six weeks, can be effective to improve flexibility (Harvey, Herbert, & Crosbie, 2002). This shows that flexibility can be influenced by activity. In the review by Holland et al. (2002), it was confirmed that even general exercise has a positive effect on the range of motion and flexibility of older adults. Current literature is too limited to confirm the exact dose response relationship of physical activity levels and flexibility. However good evidence exists to suggest that active people will at least maintain higher levels of flexibility and range of motion than their sedentary counterparts (Holland et al., 2002; Landi et al., 2014).

The literature supports that increased activity levels are associated with increased strength. Moderate evidence suggests that flexibility and range of motion may be higher in more active individuals.

Consequently, it is plausible that screening scores may differ between individuals from various activity levels (Koehle et al., 2016).

2.2.6 Previous Injury

Previous injury increases an individual's risk for subsequent injury (McCall et al., 2015). This is usually classified as a non-modifiable risk factor, as a person cannot turn back time to prevent the injury. However, it also may be argued that one can modify it through healing and rehabilitation (Roald Bahr, 2016). There are high levels of evidence to link previous injury with increased injury risk. The risk is higher the sooner the individual returns to activity. This risk decreases as time allows for improved tissue healing and condition through rehabilitation. (Hägglund, Waldén, & Ekstrand, 2013; McCall et al., 2015). Injuries have different healing rates and therefore makes this factor hard to quantify. It is important to consider previous injury as a factor when assessing an individual's injury risk. It may have value to do further targeted investigation in those individuals who have an injury history, as conventional movement screens do not account for this.

Summary of the Literature: Musculoskeletal Injury and Risk Factors

As strength and flexibility are integral to functional testing, it is important to understand how other factors affect them. High quality evidence demonstrates that older age has a negative influence on strength, flexibility and muscle control. Clear risk factors regarding gender are somewhat harder to establish. Females tend to be more flexible than males, while men have higher levels of strength and control than females. Current literature suggest that females are more prone to lower extremity injuries, as they use altered kinematics during movement strategies. Physical activity has many beneficial effects including improved strength and flexibility. Higher levels of physical activity results in better maintenance of strength, flexibility and functional ability. Injury history is an important factor when assessing injury risk.

2.4 ASSESSMENT OF INJURY RISK

Over the last two decades, injury screening started to move away from the conventional testing of repetition and duration such as sit ups and push ups. These types of tests were only focused on quantity while faulty movements patterns where disregarded. Screening then started to include the assessment of fundamental movement (Raleigh et al., 2010). Fundamental movements are the foundations of more complex movements. Many similar movements occur in various sports. Through understanding fundamental movements, it may be possible to detect dysfunction and imbalances before these develop into injury (Cook et al., 2014).

Studies in the laboratory, using high speed motion analysis, can identify kinematics that may be associated with a higher risk of injury (Imwalle et al., 2009). These techniques are expensive and time consuming, which limits their day-to-day use by clinicians. However, the knowledge gained from these mechanistic studies have contributed to the development of less complicated screening tools known as functional tests (Chimera & Warren, 2016).

2.4.1 Functional Tests

Functional tests evaluate the quality and control of movement. These include tests such as the Tuck Jump Assessment (TJA) (Myer, Ford, & Hewett, 2008), Landing Error Scoring System (LESS) (Padua et al., 2009), Star Excursion Balance Test (SEBT) (Hertel, Braham, Hale, & Olmsted-Kramer, 2006), Y-test (Plisky et al., 2009), Drop and Jump Screening Test (DJST) (Noyes, Barber-Westin, Fleckenstein, Walsh, & West, 2005) and more. These tests have all shown potential for injury prediction but are limited by only assessing one movement (Chimera & Warren, 2016). The FMS is arguably the most studied screening test, which includes a test battery for several movements.

Tests such as the Nine-Test Battery/9+ (Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2012) and the Soccer Injury Movement Screen (SIMS) (McCunn et al., 2017) have all been derived from the FMS. They were developed to improve the FMS and make it more sports specific. The increasing emergence of new functional tests suggests that clinicians and researchers have realized the potential of movement assessments, but the effective use thereof is still under development. The following section will review the current evidence relating to the use of the FMS.

2.4.2 The Functional Movement Screen (FMS)

The FMS is a 7-test battery focusing on the flexibility, stability and control of movement. Each test is graded out of 3, resulting in a maximum total of 21 as a composite score. Scores of $\leq$14 have repeatedly been associated with higher injury risk in team sports (Kiesel, Butler, & Plisky, 2014), but this relationship has not been as clear in other activities (Chimera & Warren, 2016; B. Dorrel, Long, Shaffer, & Myer, 2018; Kraus, Schütz, Taylor, & Doyscher, 2014).

Studies supporting the injury predictive abilities of the FMS have been criticized for using poor methodology (Moran et al., 2017). The reviews of Dorrel et al., (2015) and Bonazza et al., (2016) found the FMS to be a valid test and reported moderate to good injury predicting abilities. However, these reviews simply pooled results of prospective studies regardless of quality. This decreases the significance of their findings to some extent. Moran et al., (2017) recently published a high quality systematic review on FMS

validity. Each study was assessed for quality by using the 'Quality of Cohort Studies' (Q-Coh), quality assessment tool which was specifically designed for application to prospective cohort studies (Jarde, Losilla, Vives, & Rodrigo, 2013). They identified only six high quality papers (Bushman et al., 2016; Hotta et al., 2015; O'Connor, Deuster, Davis, Pappas, & Knapik, 2011; Rusling et al., 2015; Warren, Smith, & Chimera, 2015; Wiese, Boone, Mattacola, McKeon, & Uhl, 2014). All the other papers showed low levels of evidence. The descriptive characteristics of studies using the FMS to predict musculoskeletal injuries have been summarised in Table 2.1.

Table 2.1 Descriptive characteristics of studies using Functional Movement Screen™ to predict musculoskeletal injuries

Reference	Sample	Sample size (n)	Age (SD)	Cut off scores	Quality*
Bushman et al, 2016	♂ infantry brigade	2476	18-57	≤14	Good
O'Connor et al, 2011	♂ officer candidates	874	22(3)	≤14	Good
Warren et al, 2015	♂ and ♀ division I athletes	195	18-24	≤14	Good
Wiese et al, 2014	♂ American football players	144	19(1)	≤17	Good
Rusling et al, 2015	♂ professional soccer players	135	13(3)	≤14	Good
Hotta et al, 2015	♂ competitive runners	84	20(1)	≤14	Good
Knapik et al, 2015	♂ and ♀ military cadets	1045	18(1)	≤14	Acceptable
McGill et al, 2015	♂ elite police officer	53	38 (5)	≤14	Acceptable
Hammes et al, 2016	♂ veteran football players	238	44(7)	NA	Low
Kiesel et al, 2014	♂ coast guard cadets	238	NR	≤14	Low
Bardenett et al, 2015	♂ and ♀ high school athletes	185	15	≤14	Low
Garrisonet al, 2015	♂ and ♀ Division I athletes	160	17-22	≤14	Low
Kodesh et al, 2015	♀ soldiers	158	Mdn 19	≤14	Low
Schroeder et al, 2016	♂ amateur soccer players	158	24(4)	NA	Low
Butler et al, 2013	♂ firefighter trainees	108	NR	≤14	Low
Letafatkar et al, 2014	♂ and ♀ student athletes	100	18-25	≤17	Low
Mokha et al, 2016	♂ & ♀ university athletes	84	20(1)	≤14	Low
Kiesel et al, 2007	♂ pro American football players	46	NR	≤14	Low
Chorba et al, 2010	♀ division II athletes	38	19(1)	≤14	Low
Azzam et al, 2015	♂ pro basketball players	34	NR	≤14	Low
Dossa et al, 2014	♂ junior ice hockey	31	16-20	≤14	Low
Zalai et al, 2014	♂ elite soccer players	20	23(3)	NA	Low
McGill et al, 2012	♂ university basketball players	14	20(2)	NA	Low

SD, Standard deviation; Mdn, median; NR, not reported; NA, not applicable; *, quality measured by Q-Coh as reported by Moran et al (2017)

All of the high quality studies reported poor injury predictive ability, with low levels of sensitivity and specificity (Moran et al., 2017). The remaining studies have reported conflicting evidence at best (Moran et al., 2017). Varying sensitivity levels between 12-84% have been reported in different populations, with most levels closer to 50% (Moran et al., 2017). Levels of specificity are higher in general and have been reported in ranges of 46-91% (Kiesel, Butler, & Plisky, 2014; Warren et al., 2015), but the use of poor quality studies limits the interpretation thereof. Likelihood ratios (LR) were calculated for each study, to compare predictive abilities (Table 2.3). Likelihood ratios are used to indicate the probability of a disease, or in this case injury, being present or absent. Positive likelihood ratio (LR+) indicates how much the probability of the disease being present increases in the case of a positive test.

The negative likelihood ratio (LR-) indicates how much the probability of the disease being present decreases in the case of a negative test. An LR = 1 means that the test result does not change the probability. An LR > 1 indicates an increased probability that the disease is present, and an LR < 1 indicates a decreased probability that the disease is present (See Table 2.2 for interpretation of LR scores). Most studies were only able to report insignificant to minor changes in LR.

Table 2.2 Interpretation of Likelihood Ratios (McGee, 2002)

LR	Interpretation
> 10	Large and often conclusive increase in the likelihood of disease
5-10	Moderate increase in the likelihood of disease
2-5	Small increase in the likelihood of disease
1-2	Minimal increase in the likelihood of disease
1	No change in the likelihood of disease
0.5 - 1.0	Minimal decrease in the likelihood of disease
0.2 - 0.5	Small decrease in the likelihood of disease
0.1 - 0.2	Moderate decrease in the likelihood of disease
< 0.1	Large and often conclusive decrease in the likelihood of disease

LR, Likelihood ratio

Only one study reported a significant LR+ of 6 (Kiesel et al., 2007), but it is necessary to note that this study was of poor quality (Moran et al., 2017). The reported sensitivity and specificity levels from these studies are summarised in Table 2.3

Other limitations include small sample sizes, varied injury definitions and inconsistent populations including service men, professional- and recreational athletes. Overall sensitivity levels are too low to accept the composite FMS score as a valid injury predicting tool (Chimera & Warren, 2016; Moran et al., 2017).

Three recent reviews have reported moderate (Moran et al., 2015) to high (Bonazza et al., 2016; Cuchna, Hoch, & Hoch, 2016) levels of intra and inter rater reliability. Bonazza et al., (2016) reported high levels of intra-rater reliability 0.81 (95% CI, 0.69-0.92) and inter-rater reliability 0.81 (95% CI, 0.70-0.92). These findings were consistent with the work by Cuchna et al., (2016), who reported intra-rater reliability of 0.843 (95% CI = 0.645) and intra-rater reliability of 0.869 (95% CI = 0.785). Moran et al., (2015) reviewed 12 papers and assessed the reliability of the subtests as well as the composite scores.

The Intra Class Coefficient (ICC) levels were acceptable for the composite scores (≥0.60), but only four of the subtests (Deep Squat, Shoulder Mobility, Asymmetric Straight Leg Raise, Trunk Stability Push Up) reached acceptable levels (≥.40) (Moran et al., 2015). All the reviews concluded that assessors should be appropriately trained in the scoring system of the FMS to maintain reliability (Cuchna et al., 2016). Moran et al. (2015) also found higher levels of reliability among live scoring tests compared to video recordings. The high levels of reliability add credibility to the wide spread use of the FMS.

Table 2.3 Summary of Sensitivity, Specificity and Likelihood Ratios

Reference	Sensitivity (%)	Specificity (%)	+LR	-LR
Azzam et al, 2015	-	-	-	-
Bardenett et al, 2015	56	38	0.9	1.2
Bushman et al, 2016	33	82	1.8	0.8
Butler et al, 2013	84	62	2.2	0.3
Chorba et al, 2010	58	74	2.2	0.6
Dossa et al, 2014	50	70	1.7	0.7
Garrison et al, 2015	67	73	2.5	0.5
Hammes et al, 2016	-	-	-	-
Hotta et al, 2015	73	54	1.6	0.5
Kiesel et al, 2007	54	91	6.0	0.5
Kiesel et al, 2014	26	87	2.0	0.9
Knapik et al, 2015	55	49	1.1	0.9
Kodesh et al, 2015	42	63	1.1	0.9
Letafatkar et al, 2014	65	78	3.0	0.4
McGill et al, 2012	-	-	-	-
McGill et al, 2015	42	47	0.8	1.2
Mokha et al, 2016	26	59	0.6	1.3
O'Connor et al, 2011	45	78	2.0	0.7
Rusling et al, 2015	12	90	1.2	1.0
Schroeder et al, 2016	-	-	-	-
Warren et al, 2015	54	46	1.0	1.0
Wiese et al, 2014	50	43	0.9	1.2
Zalai et al, 2015	-	-	-	-

+LR, positive likelihood ratio; -LR, negative likelihood ratio; -, not reported

In conclusion, weak levels of evidence support the use of the FMS composite scores as an injury-predicting tool. However, the FMS may still be a valuable screening tool when the findings of the individual tests are interpreted in combination with sound clinical reasoning (Hewett, 2016; Kraus et al., 2014; Moran et al., 2017). Injury screening tools may still be useful in identifying weakness and asymmetry. Although the FMS shows high levels of reliability, construct validity remains a problem as reported sensitivity and specificity levels are too low.

2.5 NORMATIVE DATA

Numerous normative data studies have established reference values for physically active and relatively young participants. For example, there are studies on active service men (Teyhen et al., 2014), firefighters (Frost, Beach, Callaghan, & McGill, 2012) and athletes from various sports (Fox, O'Malley, & Blake, 2014; Moran et al., 2017; Schneiders, Davidsson, Hörman, & Sullivan, 2011). However, only a few papers have reported data on the general population (Mitchell et al., 2016). Most papers which reported normative data for the FMS found composite scores around 15, in young active populations (Kraus et al., 2014). Meanwhile, other researchers have found lower scores in other populations (Agresta, Slobodinsky, & Tucker, 2014). Mean scores as low as 12.2 ± 2.7 (Mitchell et al., 2016) have been reported in healthy older populations. The difference in mean scores may be a result of factors such as age, gender and physical activity level influencing score values (Wright et al., 2016).

2.5.1 Gender Association

No significant associations have been reported between gender and composite scores in any of the available papers. However, significant differences were reported among the individual subtests. Four papers reported that males performed better in the Stability Push Up tests (Agresta et al., 2014; Chimera, Smith, & Warren, 2015; Mitchell et al., 2016; Schneiders et al., 2011). These papers also reported that females scored higher in the Active Leg Raise and Shoulder Mobility tests. Two studies reported higher scores for the Deep Squat test in males, but these studies have made use of small sample sizes ($n \leq 45$), which makes the data difficult to interpret with confidence (Agresta et al., 2014; Loudon, Parkerson-Mitchell, Hildebrand, & Teague, 2014). Unfortunately, not all papers included data on subtest scores. Table 2.4 is a summary of the data found in normative data studies.

Overall, the trend is that females score higher in the flexibility and mobility tests, while males scored better in strength and neuromuscular control components (Koehle et al., 2016; Mitchell et al., 2016; Perry & Koehle, 2013).

2.5.2 Age Association

The association between age and FMS performance seem to be clearer than gender and FMS performance. Current research suggests that older age is associated with lower FMS composite scores (Koehle, Saffer, Sinnen, & MacInnis, 2016; Loudon et al., 2014; Mitchell et al., 2016; Perry et al., 2013; Teyhen et al., 2012). Teyhen et al., (2014) reported higher composite scores among younger participants in a cohort of military personnel (n = 247). This cohort had a low mean age, and groups were split into a "below 30" (n = 143; mean age 23.5 ± 3.8 years) and "over 30" (n = 104; mean age 33.4 ± 4.2 years) age groups. Loudon et al., (2014) reported similar results in a cohort of runners (n = 43), but also noted that younger participants scored higher in the Deep Squat, Inline Lunge and Hurdle Step Test. In this study, participants were split into "below 40" (n = 26; mean age = 29.3 ± 5.8 years) and "over 40" groups (n = 17; mean age = 49.1 ± 7.3 years).

Perry et al., (2013) were the first to use a sample cohort of the general population (n = 622). Their study reported data on six different age groups. They reported the highest FMS scores in the 20-39 age group while those above 65 years scored the lowest. Mitchell et al., (2016) reported FMS scores in an older population with an age range of 52-82. In this study they correlated age with composite scores, as well as the individual subtests. They found that older age is associated with lower FMS composite scores, while gender had no effect. The pattern of older age being associated with lower scores is most probably seen due to the decreases in general strength, flexibility and neuromuscular control with older age (Nakano et al., 2014). Although mean composite scores are lower among the older people, the patterns in subtest scoring are similar.

Table 2.4 Summary of Normative Data Studies

Reference	Sample size(n)	Sample	Gender	Mean Age	Activity level	Mean score	Sub test scoring	Summary of findings
Agresta et al, 2014	45	Runners	♂ and ♀	35 ±8; R= 22-54	Recreational runners	13 ±2	Y	No difference in composite scores; ♂ scored better in DS, TSP; ♀ scored better in ASLR
Chimera et al, 2015	92	Collegiate athletes	♂ and ♀	20 ±1	Various sports	14 ±1	Y	♂ scored better TSP and RS; ♀ scored better in SM, ASLR and ILL
Fox et al, 2014	64	Gaelic football	♂	22 ±3	Sub-elite and elite	16 ±2	Y	No difference between sub elite and elite players
Khoele et al, 2016	1113	General population	♂ and ♀	52 ± 2; R= 16–79	Not specified	13 ±3	N	Younger age groups scored better; Sex had no influence; BMI correlates negatively
Letafatkar et al, 2014	100	College athletes	♂ and ♀	23 ±3; R= 18-25	Various sports	17 ±1	Y	No difference in composite scores; ♂ scored better in TSP; ♀ scored better in ASLR, SM
Loudon et al, 2014	43	Runners	♂ and ♀	37 ±8; R= 18-40	Long distance runners	15 ±2	Y	Younger age groups scored better in DS, ILL, HST; ♀ scored better in SM and ASLR
Mitchell et al, 2016	97	Older general population	♂ and ♀	65 ±7; R= 52-83	Not specified	12 ±2	Y	No difference in composite scores; ♂ scored better in TSP; ♀ scored better in SM and ASLR; BMI correlates negatively
Perry et al, 2013	622	General population	♂ and ♀	51 ±11; R= 21-82	Various as rated by HPAPQ	14 ±2	N	Younger scored better; More active groups scored better
Schneiders et al, 2011	209	Active college students	♂ and ♀	22 ±4; R= 18-40	Various, not specified	16 ±1	Y	No difference in composite scores; ♂ performed better TSP and RS; ♀ performed better in SM and ASLR
Teyen et al, 2014	247	Military	♂ and ♀	29 ±6	Inactive to highly active	16 ±2	N	Younger age groups performed better in composite scores

Y, yes; N, no; R, range; BMI, body mass index; TSP, trunk stability push; DS, deep squat; HST, hurdle step test; ASLR, active straight leg raise; ILL , in line lunge, SM; shoulder mobility; RS, rotary stability

2.5.3 Activity Level Association

Only three studies have reported normative data in a heterogeneous population, with varying activity levels (Koehle et al., 2016; Mitchell et al., 2016; Perry et al., 2013). These papers measured physical activity levels by comparing Body Mass Index (BMI) of participants. Unfortunately, Perry et al., (2013) failed to report data on individual tests and only used composite scores in their analysis. Mitchell et al., (2016) and Koehle et al. (2016) reported data on all individual test scores which makes the normative data set more complete and may allow for better future application. All studies reported that increased BMI had a negative correlation with FMS scores. Perry et al., (2013) additionally used the Healthy Physical Activity Participation Questionnaire (HPAPQ), which is a strong and valid measure of physical activity (Tremblay et al., 2011). Higher HPAPQ scores are associated with increased physical activity levels, and positively correlated with FMS scores.

Summary of the Literature: Normative Data

The recent questioning of the FMS composite scores to predict injury, has shifted focus to individual test scores (Hewett, 2016; Wright et al., 2016). Most normative data studies have been done on homogenous young and active cohorts. Only three studies have reported normative values for the general population. Although inconsistent methodology is used in the current literature, results show that gender and age influence FMS scores. Initial evidence from suggests that higher activity levels may also have a positive correlation with FMS scores (Mitchell et al., 2016; Perry & Koehle, 2013). Future research should clarify the relationships between these variables and the subtests scores. More consistent methodology should be used to establish norms.

2.6 SUMMARY OF THE LITERATURE AND POTENTIAL LIMITATIONS

Increased activity levels have many beneficial health effects ranging from decreased risk of chronic diseases, increased mobility and improved musculoskeletal health (Baudry, 2016; Nunan et al., 2013; Zampieri et al., 2015). In the general population, there is a high incidence of musculoskeletal injuries in active and non-active individuals (Hootman et al., 2002). These injuries may result in a long time-loss from activity participation and may also prevent return to work in severe cases. Furthermore, musculoskeletal injuries can also be an economic burden (Mock & Cherian, 2008). Injuries result in high medical expenses for national health systems and medical aid schemes (Brooks, 2006; Hoy et al., 2014). By preventing injuries people will be able to live more active lifestyles and medical expenses could be decreased (Hoy et al., 2014).

Injury prevention is a relatively new field in medicine, with growing interest from many areas (Bittencourt et al., 2016; van Dyk & Clarsen, 2017). The main aim of this field of research to decrease injury incidence and therefore allow individuals to participate in physical activity without limitations. Through the understanding of injury aetiology, risk factors and mechanisms of injury preventative measures may be developed. Sports has driven the injury prevention field to find fast and accurate ways to establish risk factors and prevent injuries (Wright et al., 2016). Screening tests have been developed to identify risk factors that may lead to injury (McCall et al., 2015). There is currently no consensus on which screening test works best. The literature has seen a move away from conventional tests that simply assess number of repetitions and time to completion (e.g. sit ups, push ups) in favour of functional testing (Chimera & Warren, 2016; Kiesel et al., 2013). Functional testing involves the evaluation of symmetry, stability and control of movement. Insufficiency of these factors, may lead to injury (Beckham, 2010; Cook et al., 2014).

The FMS is one of the functional screening tests that has grown rapidly since its inception and is now widely used in sports (Wright et al., 2016). The main reasons for the popularity of the FMS is that it is simple, inexpensive and time efficient. There has been recent interest to use the FMS in the general population as well. Although the FMS has shown potential to serve as a screening test, many factors relating to its use are still unclear.

2.6.1 Limitations

2.6.1.1 Sensitivity

The use of the FMS as an injury predicting tool was recently strongly debated (Bahr, 2016; Wright et al., 2016). Kiesel et al. (2007) proposed that a composite score of 14 may be used as a cut-off score to predict injuries in American football players. A number of studies have identified mean scores of ±15 in healthy populations, seemingly adding credibility to this finding. (Wright et al., 2016). However, other studies have failed to reproduce these findings in other populations (Chimera & Warren, 2016; Moran et al., 2017; Wiese et al., 2014)..

The FMS was criticized for not being sensitive or specific enough to be an injury predictive test. Recent reviews have reported sensitivity levels below 50% (Dorrel et al., 2015; Moran et al., 2017), which translates into the injury predicting abilities being less than the outcome after flipping a coin. A screening test must be able to distinguish between those people with and without risk. Wright (2016) and Bahr (2016) therefore stated that a test cannot be a screening test if it lacks sensitivity and specificity. Hewett (2016) strongly contested these statements, arguing that screening tests may still have other beneficial uses.

Although screening tests may not be able to predict injury with great accuracy, it may still identify individuals at risk. Other positive factors associated with screenings include athlete education, engagement with the medical team, objective identification of deficits, use of evidence based interventions and possible performance enhancement (Hewett, 2016). A major problem with injury prediction studies is the use of varying injury definitions and small homogenous samples. Cut-off scores may change in groups with different physical activity levels, genders and ages (Wright et al., 2016). These factors should be clearly understood to make clear assumptions from screening scores.

2.6.1.2 Associative factors

Age

Older age is associated with decreased muscle strength, flexibility and balance (Daly et al., 2013). Age may affect scores as stability, mobility and control form the basis of fundamental testing. Only five papers have reported normative data for various age groups. However, inconsistent methodology makes the results difficult to interpret. Two of the studies merely split their samples into two age groups (Loudon et al., 2014; Teyhen et al., 2014). Loudon et al., (2014) may also be criticized for using a small study sample (n = 43). Only three studies have used a sample of the general population (Koehle et al., 2016; Mitchell et al., 2016; Perry et al., 2013). Perry et al., (2013) used a large sample (n = 622) ranging from 21- 82 years but failed to report data on individual test scores. They used inconsistent age groupings, with some groups ranging over 20 years and other groups ranging only five years. Since then, only two studies have used similar samples (Koehle et al., 2016; Mitchell et al., 2016). Koehle et al. 2016 reported data on a larger sample (n = 1113) ranging from 16-79 years and used more consistent age groupings of 15 years. Between the three studies using general population cohorts, only Mitchell et al., (2016) reported data for all the individual subtests. However, this study population was limited to individuals older than 52 years of age. Although all studies reported a negative correlation between older age and composite scores, there is no clear evidence for the association between age and the subtests. More high-quality studies are needed to form a clear understanding of how age influences functional screening scores.

Gender

Flexibility, range of motion, strength and neuromuscular control differs between genders (Intolo et al., 2009; Kienbacher et al., 2015; Stoll et al., 2000). Therefore, it can be assumed that gender will affect functional test scores. Research has shown that females have increased range of motion and flexibility, while males have higher levels of strength and neuromuscular control (Willigenburg & Hewett, 2017). It stands to reason that females may perform better in flexibility components of functional screening, while men perform better in strength components.

While this pattern has been noted in several studies, only one study has reported similar findings in the general population (Mitchell et al., 2016). As functional screenings evaluate several attributes, it is important to understand the relationship between subtest scores and gender. More data in this field may allow for better understanding of how gender affects functional screening scores.

Physical activity

Considering the positive effects of physical activity, it can be assumed that this can also affect screening scores. Interestingly, the three recent studies by Perry et al., (2013), Koehle et al., (2016) and Mitchell et al, (2016), established that decreased levels of physical activity were also associated with a decline of FMS scores. The studies used BMI as an indirect measure of physical condition and reported a negative correlation with FMS composite scores. Although increased BMI is associated with decreased mobility in ages over 65 years, it is not a reliable predictor of physical activity levels in younger populations (Barry et al., 2014). All three studies reported that BMI had a negative correlation with FMS composite scores. Perry et al., (2013) arguably used the most valid measure of physical activity by including HPAPQ scores (Tremblay et al., 2011). Not surprisingly, higher HPAPQ scores were strongly associated with higher composite FMS scores. The general population consists of individuals from many different activity level backgrounds. Therefore, it is important to use validated measures of activity levels to establish clear association in future research.

2.6.2 Rationale for the Study

Most of the available research on normative data is done in young active populations. The use of homogenous samples has limited the interpretation of these results to those populations (Mitchell et al., 2016). Therefore, it is unclear how factors such as age, gender and physical activity influences scoring in other cohorts. Only limited research exists on functional screening scores in the general population.

The aim of the study is to describe associations of different variables such as age, gender and physical activity with EMS scores, the functional screening test adapted from the FMS and which is used at the Sports Science Institute of South Africa. The findings could also provide reference values to make the EMS a more relevant screening tool for adults across different age groups and activity levels.

CHAPTER THREE

ESTABLISHING ASSOCIATIONS FOR THE EVALUATION OF MOBILITY SCREEN (EMS) IN AN ADULT SOUTH AFRICAN POPULATION

INTRODUCTION

Musculoskeletal injuries are one of the main reasons for time loss from physical activity (Hootman et al., 2002). This has driven researchers to find ways of reducing and preventing injuries by developing pre-participation screening tools. The goal of these screening tools is to identify risk factors, which could increase injury risk.

The Functional Movement Screen (FMS) has been developed, with the purpose to assess symmetry, flexibility and control. The scoring system assesses quality and efficiency of movement rather than amount or speed of repetitions. It consists of seven functional movements (subtests), that are scored individually (Cook et al., 2014). Two recent high quality systematic reviews (Bonazza et al., 2016; Moran et al., 2015), have assessed the validity of the FMS. Both studies reported high levels of intra- and inter-rater reliability, which adds credibility to its widespread use.

The Evaluation of Mobility Screen (EMS) is an adaptation of the FMS and was developed at the High-Performance Centre at the Sports Science Institute of South Africa. The EMS was adapted from the FMS by changing one of the subtests used to assess trunk mobility and stability. The composite scoring system however remains the same. The EMS uses the Seated Rotation Test (Johnson & Grindstaff, 2010) instead of the Rotary Stability Test. The Rotary Stability Test, as included in the FMS, has been found to have questionable reliability and validity by a recent review (Bonazza et al., 2016). The Seated Rotation Test has some of the highest inter and intra-rater reliability among tests, that assess trunk mobility (Johnson, Kim, Yu, Saliba, & Grindstaff, 2012). During the Seated Rotation Test, the use of a dowel allows for easier visualization of anatomical landmarks. The seated position adds greater stability to the movement and decreases shaking of the individual, which makes assessment easier. The Trunk Rotation test does not assess the full range of motion of trunk rotation and requires the individual to stand in a four-point kneeling position. It may also be argued that this is not a functional position for daily activity. The Seated Rotation Test assesses the overall flexibility and stability of the lumbar and thoracic spine as it is moved through the full range of movement. Many sporting and daily activities requires full rotation of the trunk. Therefore, the Seated Trunk Rotation test may be viewed as a suitable replacement for the Rotary Stability Test.

Each of the seven subtests is scored on a scale of 0-3 points, which adds up to a maximum total of 21. Recent systematic reviews (Bonazza et al., 2016; Moran et al., 2015) has reported that individuals with a composite score of 14 and below, have a higher risk of injury. Previous studies have shown that the FMS is a valid assessment tool to predict injury risk in American football players (Kiesel et al., 2007), military (Lisman, O'Connor, Deuster, & Knapik, 2013) and college athletes (O'Connor et al., 2011). However, the

relevance of these findings to the general population has been questioned (Bahr, 2016; Hewett, 2016). Most of the studies have been conducted by assessing active populations, under 40 years of age (Koehle et al., 2016; Perry et al., 2013)

There is conflicting evidence regarding the effect of gender on FMS scores. Most previous studies report no significant differences between the composite scores of males and females. However, some of the subtest scores have been found to differ (Agresta et al., 2014; Chimera et al., 2015; Loudon et al., 2014). This has been attributed to the possibility that females score lower than males on the strength components, while scoring higher on flexibility and stability tests. The correlation between gender and FMS scores is therefore not fully understood, as very few of the current populations include females in their studies. It has also been suggested that increasing age could have a negative correlation with FMS scores. Older age is associated with sarcopenia which decreases in flexibility, mobility and strength that in older populations (Daley et al., 2000; Zampieri et al., 2015). This has yet to be confirmed as most studies have only used young populations. Only three studies (Koehle et al., 2016; Mitchell et al., 2016; Perry et al., 2013), have assessed the association between different activity levels and FMS scores. A positive correlation was found between FMS scores and increased activity levels. Unfortunately, inconsistent methodology and indirect measures of physical activity levels have been used.

Currently there is limited evidence on the association of age, gender and physical activity levels in the scoring of the FMS, and by implication the EMS. To accept the EMS as a screening tool for the general population, it is important to understand the effect of these three factors on the EMS scores. Therefore, the aim of this study is to establish clarity over the association between age, gender and physical activity levels on EMS outcomes.

Keywords: *"injury prevention", "injury risk", "injury screening", "preparticipation screening", "Functional Movement Screen (FMS)", "reference values", "normative values".*

3.1. AIMS AND OBJECTIVES

3.1.1 Aim

The aim of the study was to describe the association between age, gender and physical activity on EMS scores.

3.1.1.1 Objective

To evaluate and compare differences in EMS scores relating to age, gender and physical activity levels.

3.2 METHODOLOGY

3.2.1 Study Design

This was a quantitative study, with a descriptive, correlational design.

The data were gathered during the PhD thesis (The association between cardiorespiratory fitness and performance in a submaximal stepping test standardized for energy expenditure) of Linet Huchu, with support from the High Performance Centre (HPC), Sport Science Institute of South Africa. The initial study was approved for ethical clearance on the 12th of April 2013, by the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town (HREC REF 161/2013) (Appendix I). The current study was submitted to and approved by the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town (HREC REF 152/2017) (Appendix II). The data were not analysed or used for any other study prior to the current study.

3.2.2 Participants

For this study, it was necessary to have two groups separated by gender, varying in age (20 to 60 years), and physical activity levels. Physical activity levels were graded by the Global Physical Activity Questionnaire (GPAQ)(Bull et al., 2009). The levels of classification are "*below the recommended level of physical activity*", "*achieved the recommended level of physical activity*", or "*above the recommended level of physical activity*". To populate each cell with 10 participants (age/gender/physical activity), 240 participants had to be recruited. See Table 3.1 for a description of these cells.

Table 3.1 Example of Sample Size Defined by Age and Activity Level

	Males				Females			
AGE	**Below**	**Achieved**	**Above**	**Total**	**Below**	**Achieved**	**Above**	**Total**
20-30	10	10	10	30	10	10	10	30
31-40	10	10	10	30	10	10	10	30
41-50	10	10	10	30	10	10	10	30
51-60	10	10	10	30	10	10	10	30
TOTAL	40	40	40	120	40	40	40	120

Below: "below the recommended level of physical activity"
Achieved: "Achieved the recommended level of physical activity"
Above: "above the recommended level of physical activity"

3.2.3 Inclusion Criteria

Healthy male and female participants with a range physical activity levels where included in the study. Participants had to be between 20 and 60 years of age.

3.2.4 Exclusion Criteria

Participants were excluded if they had any orthopaedic problems, which could affect participation in the study. Individuals using chronic medication that might alter cardiorespiratory and metabolic responses to exercise were also excluded. Participants with body mass less than 50 kg or more than 100 kg were excluded. Any participant who failed to complete the testing procedure were excluded.

3.2.5 Recruitment

Recruitment of participants was conducted by various methods ranging from distribution of invitations through e-mail, fliers and word of mouth. Invitations were also sent to staff and students from the Sport Science Institute of South Africa. Initially it was planned to recruit a group of 240 participants that would consist of 50% males and 50% females. The participants were divided into four separate age groups between 20-60 years, and classified by their activity levels

During recruitment, more participants between ages of 20-30 responded, hence the enlarged sample (n = 262). In total 28 participants had to withdraw from the study, citing reasons from commitments to work, commitments at home or being sick as their reasons for withdrawal. Two hundred and sixty-two participants completed the study, of which 135 were male and 127 were female (Table 3.2).

Table 3.2 Participants Defined by Age and Activity Level (n = 262)

	Males				Females			
AGE	**Below**	**Achieved**	**Above**	**Total**	**Below**	**Achieved**	**Above**	**Total**
20-30	10	12	25	47	10	11	14	35
31-40	8	8	10	26	11	9	12	32
41-50	8	10	13	31	9	10	9	28
51-60	10	10	11	31	10	12	10	32
TOTAL	36	40	59	135	40	42	45	127

Below: "below the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Above: "above the recommended level of physical activity"

3.2.6 Sample Size

The design described in the above-mentioned table guarantees heterogeneity amongst the groups. This is important for establishing relationships between variables and EMS scores. The power analysis was done with maximum rates of statistical error of 5% (Type 1) and 20% (Type 2 error). It was established that a sample size of n = 10 per cell, had the power to detect a correlation of r = 0.8.

Considering that the data from each cell would be merged, it was accepted that the heterogeneity of the sample would increase. This would allow for clearer establishment of the relationships of the variables.

3.2.7 Measurement Instrumentation

The participants were assessed at the High-Performance Centre at of the Sports Science Institute of South Africa. Each participant completed the Global Physical Activity Questionnaire (GPAQ) (Appendix III) in conjunction with the EMS. The tests were conducted by trained personnel and reliability between testers was confirmed before the study started.

3.2.7.1 Global Physical Activity Questionnaire (GPAQ)

The GPAQ survey was chosen due to the low cost and ease of use (Bull, T. S., and Armstrong, T., 2009). The GPAQ is standardised and widely used in developing countries as an indirect measurement of activity levels (Hallal et al., 2012). The GPAQ comprises of questions grouped to capture physical activity undertaken in three different domains. These domains are work, travel and recreation. The captured data are converted into MET minutes. According to the World Health Organization a minimum of 600 MET minutes per week are required to have substantial health gains (World Health Organization, 2015). Any

person to score less than 600 is classified as “below the recommended activity level”. Scores between 600 and 2400 is classified as “achieved recommended activity level”. Scores above 2400 is classified as “above recommended activity level”. Participants were grouped according to their individual scores on the GPAQ.

3.2.7.2 The Evaluation of Mobility Screen (EMS)

The EMS, adapted from the FMS is used to assess mobility and stability and determine if the participant has a fundamental movement dysfunction. It consists of seven tests that have been designed to evaluate mobility and stability. The tests are the Overhead Squat, Single Leg Hurdle, Split Squat, Asymmetric Leg Raise, Shoulder Mobility, Stability Push Up and The Seated Trunk Rotation Test. The EMS test takes ± 12 minutes to complete. Please refer to Table 3.3 for scoring guidelines.

Table 3.3 Scoring Guidelines for the EMS (Cook et al., 2014)

SCORE	Guidelines
0	If any pain is present during movement Test should be stopped immediately Continue with next test Refer to clinician for full assessment of pain
1	Unable to perform movement Unable to get into starting position Associated with gross limitation in stability and mobility Prescription of a relative corrective program is needed Performance conditioning should be ceased until a score of 2 is reached
2	Able to complete movement, with compensation A corrective program should be followed
3	Movement completed without compensation Demonstrates good movement and has no evident dysfunction Assessor should be strict when scoring

A description of each subtest follows;

Overhead Squat (Cook et al., 2014)

The Overhead Squat is an important movement for all sports. It is the basic position for most activities that entails power movements of the legs. This is a bilateral test. It assesses symmetry and mobility of the lower limbs (hips, knees and ankles), thoracic spine and shoulders. For the starting position, the participant should place their feet should shoulder width apart. Feet should be aligned in the sagittal plane. The participant then holds a dowel above the head, with their elbows flexed at 90°, gripping it with a pronated overhand grip.

The participant then slowly descends into the deepest possible squat position, while ensuring that the dowel is maintained in alignment with the feet. The movement can be repeated up to three times and the maximum score is recorded.

Single Leg Hurdle (Cook et al., 2014)

The Single Leg Hurdle test is an assessment of the participant's mechanics during the motion of taking a step. The test requires the participant to have adequate mobility and coordination between the hips and thorax. It tests for bilateral stability and mobility of the lower limbs (hips, knees and ankles). For the starting position the participant places their feet together, with the toes touching the base of the hurdle. The hurdle is adjusted to the height of the participant's tibial tuberosity. The dowel is held behind the neck to rest on the shoulders. The step is started with the foot in dorsiflexion and ended with the heel of the stepping leg touching the floor. The foot is not allowed to touch the hurdle. The test can be performed up to three times. The test is performed with the left and right leg. Points are awarded according to accuracy of performance. The lowest score between the two legs is accepted as the total.

Split Squat (Cook et al., 2014)

The test assesses the ability of the body to stabilise itself when placed in a position that makes it vulnerable to lateral and rotational stresses. It tests for mobility of the hip and ankles as well as knee stability. The participant is instructed to stand on a board or line, with one foot in front of the other. A dowel is held behind the back, with the hand opposite to the leading foot gripping the dowel at the cervical level. The hand on the same side as the leading foot grips the dowel at the lumbar level. A measurement equating to the length of the participant's tibia is marked out on the board, starting from the toes of the back foot. The participant is then instructed to step forward and place the heel of the leading for on the allocated mark. The knee of the back foot is then lowered to touch the floor, after which the individual can then slowly return to the starting position. This test considers symmetry and it is repeated with both sides. The test can be performed up to three times per leg. The lowest score between the two sides is accepted as the total.

Shoulder Mobility (Cook et al., 2014)

This test assesses bilateral shoulder mobility. It pairs maximal abduction with external rotation and maximal adduction with internal rotation. Before the test starts the participant is asked to perform a shoulder clearing test, by placing an open palm on the contra-lateral shoulder and then flexing the shoulder upwards. If any pain is present the participant is not allowed to complete the test. The test begins by taking a measurement of the hand from the wrist crease to the end of the 3rd digit. The participant is then asked to make a fist with the hands by placing the thumb inside the fingers.

This is followed by placing the one arm in maximal abduction and external rotation, while placing the opposite arm in maximum adduction and internal rotation. The hands should remain in a fist and placed behind the back in one motion. The measurement between the fists is then recorded. This test can be repeated up to 3 times. The measurement is taken for the abducted shoulder. If the distance between the fists is more than the length and a half of the hand, the score should be 1. The lowest score between the two sides is then taken as the total.

Asymmetric Leg Raise (Cook et al., 2014)

The Asymmetric Leg Raise test assesses the participant's ability to dissociate lower extremity movement from the trunk. This requires the participant to maintain stability in the trunk while actively lengthening the hamstring and gastrocnemius. The starting position is in the supine position. Before the test begins, the mid-point between the anterior superior iliac spine and the superior border of the patella should be identified. A dowel is then placed at this point, perpendicular to the floor. The participant is then prompted to raise the tested leg while maintaining dorsiflexion at the ankle and extension of the knee. The knee and heel of the non-test leg should maintain in contact with the floor at all times. The non-test leg is not allowed to externally rotate. The position of the malleolus in relation to the dowel should be noted. The lowest score between the two sides is then recorded as the total.

Stability Push Up (Cook et al., 2014)

The Stability Push Up test is used to assess trunk stability while performing a bilateral symmetrical closed-chain movement of the upper limb. The participant assumes the starting position by lying prone. Males position their hands at the level of their forehead, while females position their hands at the level of their chin. A dowel is held in place by the tester on the participants back. The dowel should make contact with the sacrum, thoracic spine and head of the participant. The tester grips the dowel at the lumbar level, with fingers touching the lumbar spine. The participant then performs a push up from this position. The participant should not lose contact with the dowel during any stage of the test. The test may be performed up to three times. Only the maximum score is recorded.

Seated Rotation (Johnson & Grindstaff, 2010)

The Seated Rotation test evaluates the mobility of the thoracic spine. The participant assumes the starting position by sitting on a bench with the knees flexed to 90 °. The lower legs are crossed to a point where the medial malleolus is in line with proximal head of the opposite tibia. The participant sits erect while holding the dowel against the chest with the upper extremities crossed and hand placed on opposite shoulders. The dowel should maintain contact with the sternum. A dowel is held vertically in front of the participant, in line with the sternum as a reference point.

The participant starts the test by rotating the trunk as far as possible to one side. The participant should aim to maintain the dowel in the transverse plane until it touches the vertical dowel. The test is repeated to the opposite side. The participant is scored by the degree of moment in relation with the vertical dowel. The test may be repeated up to three times. The lowest score between the two sides is recorded as the total.

3.2.7.3 Reliability and Validity

The inter- and intra-rater reliability for the use of FMS has shown moderate levels of evidence. (Bonazza et al., 2016; Moran et al., 2015). Moderate to strong evidence exist for the use of the subtests of the FMS. Moran et al. (2015) reported moderate levels of inter- intra-rater reliability for the Deep Squat, Single Leg Hurdle, Split Squat, Asymmetric Leg Raise, Shoulder mobility and Stability Push Up tests, when using live assessment. Video analysis provided conflicting evidence of tester reliability and is not recommended for scoring any of the tests (Moran et al., 2015; Palmer et al, 2017; Smith et al., 2013). The Seated Trunk Rotation Test has shown evidence for moderate to strong levels of reliability and low levels for measurement error to assess trunk mobility (Johnson et al., 2012).

3.2.8 Procedure

Participants completed informed consent forms (Appendix IV) before the start of the study. All participants were screened by the American College of Sports Medicine (ACSM) pre-participation screening tool before in any testing. Physical activity was graded by the GPAQ following an interview with the participant.

Before the EMS testing, each participant completed a warm up of stretching and five minutes of stationary cycling. The different tests from the EMS were thoroughly explained and demonstrated before being assessed. Each participant had to complete all seven subtests of the EMS. The subtests were scored individually according to the specific criteria described on pages 33-36 of the study. The scores were then combined to give a composite value.

3.2.9 Statistical Analyses

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25 (IBM Corp). The descriptive data describing the participant characteristics are presented as the mean and standard deviation (SD). The scores for performance in each test are discrete with finite values and are presented as the median and interquartile range. The total scores are expressed as a frequency distribution. A chi-square test was performed at 5% level of significance to test the null hypothesis of no association between gender, age and physical activity level on EMS scores. A Kruskall-Wallis one-way ANOVA was used to determine differences between groups for total scores. Significance was accepted at $p < 0.05$.

3.2.10 Ethical Considerations

The study was performed in accordance with the principles of the Declaration of Helsinki (Fortaleza, Brazil, 2013). The proposal was submitted to the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town for ethics approval. Ethical clearance was received on 10th March 2017. (HREC 152/2017) (Appendix II).

All participants were required to provide written informed consent (Appendix IV). The participants were provided with a subject information sheet with explanations and instructions relating to purpose, procedures and risks during the study (Appendix V). The participants had the right to withdraw from the study at any time. At the end of the data collection of the initial study, the participants received a report of their data. The data were kept confidential and anonymous. The data were originally captured by hard copy and will be stored at the South African Institute for Sports Science for six years. The data has also been transferred to electronic format which will be kept on an encrypted hard drive. There was no risk to the participants during this study.

3.3 RESULTS

3.3.1 Descriptive characteristics

The descriptive characteristics of males and females are shown in Table 3.4a and Table 3.4b respectively. The data are described according to age group and level of physical activity (above, achieved and below the daily recommended level). Two hundred and sixty-two participants completed the study, of which 135 were male (Table 3.4a) and 127 were female (Table 3.4b).

Table 3.4a Physical Characteristics of Male Participants (n = 135). Data expressed as mean ± standard deviation

Variable	Physical activity	20-30 years	31-40 years	41-50 years	51-60 years	All age groups
Age (years)	***All***	**25 ± 3 (47)**	**35 ± 3 (26)**	**45 ± 3 (31)**	**56 ± 2 (31)**	**39 ± 12 (135)**
	Above	*24 ± 3 (25)*	*35 ± 3 (10)*	*45 ± 3 (13)*	*55 ± 3 (11)*	
	Achieved	*27 ± 3 (12)*	*35 ± 3 (8)*	*45 ± 3 (10)*	*56 ± 2 (10)*	[20 - 60]
	Below	*26 ± 3 (10)*	*36 ± 3 (8)*	*46 ± 3 (8)*	*57 ± 2 (10)*	
Stature (cm)	**All**	**178 ± 7.6 (47)**	**180.1 ± 6.2 (26)**	**178.3 ± 7.0 (31)**	**174.5 ± 7.8 (31)**	**177 ± 7 (135)**
	Above	*178.9 ± 6.9 (25)*	*180.5 ± 7.4 (10)*	*177.1 ± 5.8 (13)*	*177.8 ± 7.5 (11)*	
	Achieved	*177.8 ± 4.6 (12)*	*179.8 ± 6.7 (8)*	*182.3 ± 7.0 (10)*	*174.2 ± 8.3 (10)*	[159 – 195]
	Below	*175.9 ± 11.6 (10)*	*179.9 ± 4.5 (8)*	*176.0 ± 7.6 (8)*	*171.1 ± 6.6 (10)*	
Body mass (kg)	**All**	**74.4 ± 10.3 (47)**	**81.9 ± 10.8 (26)**	**83.7 ± 11.8 (31)**	**77.4 ± 12.1 (31)**	**78.7 ± 11.7 (135)**
	Above	*72.2 ± 8.9 (25)*	*80.0 ± 10.9 (10)*	*80.0 ± 13.8 (13)*	*77.8 ± 10.1 (11)*	
	Achieved	*78 ± 10.4 (12)*	*78.8 ± 8.6 (8)*	*87.5 ± 8.3 (10)*	*75.7 ± 12.5 (10)*	[48 – 106]
	Below	*75.7 ± 12.9 (10)*	*87.5 ± 12 (8)*	*85.0 ± 11.6 (8)*	*78.6 ± 14.6 (10)*	
BMI (kg/m^2)	**All**	**23.6 ± 3.1 (46)**	**25.3 ± 3.5 (26)**	**26 ± 3.4 (31)**	**25.5 ± 4.0 (31)**	**25 ± 4 (134)**
	Above	*22.6 ± 2.4 (25)*	*24.4 ± 3.4 (10)*	*25.5 ± 4.2 (13)*	*24.6 ± 2.6 (11)*	
	Achieved	*24.4 ± 3.1 (12)*	*24.5 ± 1.3 (8)*	*26.3 ± 1.3 (10)*	*24.9 ± 3.7 (10)*	[18 – 37]
	Below	*25.1 ± 4.1 (9)*	*27.2 ± 4.7 (8)*	*26.4 ± 4.3 (8)*	*26.9 ± 5.4 (10)*	
Body fat %	**All**	**15.5 ± 4.8 (46)**	**19.9 ± 5.4 (26)**	**22.4 ± 5.2 (31)**	**22.1 ± 5.8 (31)**	**20 ± 6 (134)**
	Above	*13.4 ± 4.0 (25)*	*17.8 ± 4.8 (10)*	*19.6 ± 5.7 (13)*	*22.4 ± 4.8 (11)*	
	Achieved	*17.2 ± 4.8 (12)*	*20.38 ± 6.3 (8)*	*24.3 ± 4.0 (10)*	*21.4 ± 6.3 (10)*	[7 – 34]
	Below	*19.1 ± 4.0 (9)*	*22.1 ± 4.9 (8)*	*24.3 ± 3.7 (8)*	*22.5 ± 6.9 (10)*	
METS	**All**	**2546 ± 1595 (47)**	**1971 ± 1420 (26)**	**1930 ± 1275 (31)**	**1509 ± 1005(31)**	**2056 ± 1413 (135)**
	Above	*3669 ± 1155 (25)*	*3254 ± 1265 (10)*	*3134 ± 903 (13)*	*2536 ± 789 (11)*	
	Achieved	*1865 ± 843 (12)*	*1268 ± 466 (8)*	*1422 ± 493 (10)*	*1300 ± 489 (10)*	
	Below	*554 ± 208 (10)*	*1072 ± 1042 (8)*	*610 ± 454 (8)*	*588 ± 397 (10)*	[0 – 6720]

() = sample size
[] = Range
BMI = Body Mass Index
METS = Self-reported Metabolic Equivalent

Table 3.4b Physical Characteristics of Female Participants (n = 127). Data expressed as mean ± standard deviation

Variable	Physical activity	20-30 years	31-40 years	41-50 years	51-60 years	All age groups
Age (years)	***All***	**25 ± 3 (35)**	**35 ± 3 (32)**	**47 ± 3 (28)**	**55 ± 3 (32)**	**40 ± 12 (127)**
	Above	*24 ± 3 (14)*	*35 ± 3 (11)*	*47 ± 3 (9)*	*55 ± 3 (10)*	
	Achieved	*26 ± 3 (11)*	*34 ± 3 (9)*	*47 ± 3 (10)*	*55 ± 3 (12)*	[21 - 60]
	Below	*25 ± 4 (10)*	*35 ± 4 (12)*	*46 ± 3 (9)*	*55 ± 2 (10)*	
Stature (cm)	**All**	**167 ± 6.4 (35)**	**164.2 ± 6.5 (32)**	**165.6 ± 6.7 (28)**	**165.6 ± 7.1 (32)**	**166 ± 7 (127)**
	Above	*167.9 ± 5.6 (14)*	*166.7 ± 5.0 (11)*	*168.3 ± 7.4 (9)*	*163.8 ± 5.5 (10)*	
	Achieved	*166.6 ± 5.8 (11)*	*167.2 ± 5.3 (9)*	*162.5 ± 6.7 (10)*	*165.7 ± 8.5 (12)*	[152 – 181]
	Below	*166.3 ± 8.3 (10)*	*159.5 ± 6.2 (12)*	*166.4 ± 5.1 (9)*	*167.4 ± 6.7 (10)*	
Body mass (kg)	**All**	**66.1 ± 10.3 (35)**	**66.7 ± 9.5 (32)**	**67.9 ± 10.9 (28)**	**65.1 ± 9.2 (32)**	**67 ± 10 (127)**
	Above	*65.9 ± 11.1 (14)*	*65.7 ± 6.1 (11)*	*66.4 ± 13.4 (9)*	*62.0 ± 9.3 (10)*	
	Achieved	*60.8 ± 6.5 (11)*	*66.6 ± 13.2 (9)*	*68.9 ± 9.9 (10)*	*62.5 ± 6.7 (12)*	[48 – 98]
	Below	*72.3 ± 9.8 (10)*	*67.7 ± 9.5 (12)*	*68.4 ± 10.3 (9)*	*71.3 ± 9.5 (10)*	
BMI (kg/m^2)	**All**	**23.5 ± 4 (35)**	**24.9 ± 3.4 (31)**	**24.8 ± 4.5 (28)**	**23.6 ± 3.1 (32)**	**24 ± 4 (127)**
	Above	*23.2 ± 3.7 (14)*	*24.0 ± 2.2 (10)*	*26.3 ± 5.2 (9)*	*23.1 ± 3.4 (10)*	
	Achieved	*21.6 ± 2.4 (11)*	*23.7 ± 3.6 (9)*	*26.3 ± 1.3 (10)*	*22.5 ± 2.4 (12)*	[17 – 38]
	Below	*26.2 ± 3.4 (10)*	*27.2 ± 4.7 (12)*	*24.6 ± 3.1 (9)*	*25.4 ± 3.0 (10)*	
Body fat %	**All**	**28.5 ± 4.7 (35)**	**30.2 ± 4.2 (31)**	**32.5 ± 4.3 (28)**	**32.0 ± 4.092 (32)**	**31 ± 5 (127)**
	Above	*28.3 ± 4.7 (14)*	*28.6 ± 2.1 (10)*	*30.8 ± 5.3 (9)*	*30.0 ± 4.8 (10)*	
	Achieved	*26.6 ± 4.0 (11)*	*29.0 ± 6.0 (9)*	*33.9 ± 4.6 (10)*	*31.3 ± 3.0 (12)*	[18 – 44]
	Below	*31.0 ± 4.8 (10)*	*32.7 ± 6 (12)*	*32.7 ± 2.6 (9)*	*34.9 ± 3.1 (10)*	
METS	**All**	**1784 ± 1001 (35)**	**1361 ± 992 (32)**	**1608 ± 1340 (28)**	**1717 ± 1314 (32)**	**1622 ± 1161 (127)**
	Above	*2532 ± 781 (14)*	*2511 ± 529 (11)*	*3015 ± 1142 (9)*	*3166 ± 1166 (10)*	
	Achieved	*1885 ± 499 (11)*	*1219 ± 391 (9)*	*1612 ± 443 (10)*	*1434 ± 695 (12)*	
	Below	*624 ± 499 (10)*	*413.3 ± 297 (12)*	*197 ± 276 (9)*	*610 ± 442 (10)*	[0 – 5520]

() = sample size
[] = Range
BMI = Body Mass Index
METS = Self-reported Metabolic Equivalent

3.3.2 Total EMS scores

The total EMS scores for males, females and combined groups are shown in Table 3.5 Data are expressed as median and interquartile ranges. There is a clear pattern in the median scores of male participants. The 20-30 year group had the highest median score of 18 (IQR = 4). The 31-40 and 41-50 year old group displayed the same median score of 16 (IQR = 3). The oldest group had the lowest median score of 15 (IQR = 4).

The pattern is not as clear in the female group. The 20-30 year old females displayed a median of 16 (IQR=3). The 31-40 and 41-50 year old groups displayed the highest median scores. The 31-40 group had a median of 17 (IQR = 3), while the 41-50 old group had similar median of 17 (IQR = 2). The 51-60 year old group displayed the lowest median of 15 (IQR = 3).

There was no significant difference in the median scores when the collective data were compared between genders [Males (Median =16, IQR = 4); Females (Median =16, IQR = 3)].

Table 3.5 Total EMS Scores for Male, Female and Combined Groups

Gender	Age Groups	Median	Lower Limit	Upper Limit	n
Males	**All**	**16**	**14**	**18**	**135**
	20-30	18	15	19	47
	31-40	16	14	17	26
	41-50	16	15	18	31
	51-60	15	13	17	31
Females	**All**	**16**	**15**	**18**	**127**
	20-30	16	15	18	35
	31-40	17	15	18	32
	41-50	17	15	17	28
	51-60	15	14	17	32
Combined	**All**	**16**	**15**	**18**	**262**
	20-30	17	15	19	82
	31-40	17	15	18	58
	41-50	16	15	18	59
	51-60	15	14	17	63

The percentiles were calculated for total score for each age. The 10^{th}, 30^{th}, 50^{th}, 70^{th} and 90^{th} percentiles were plotted for male and female participants (Figure 3.1). There was a general decrease with increasing age, but this did not follow a predictable pattern.

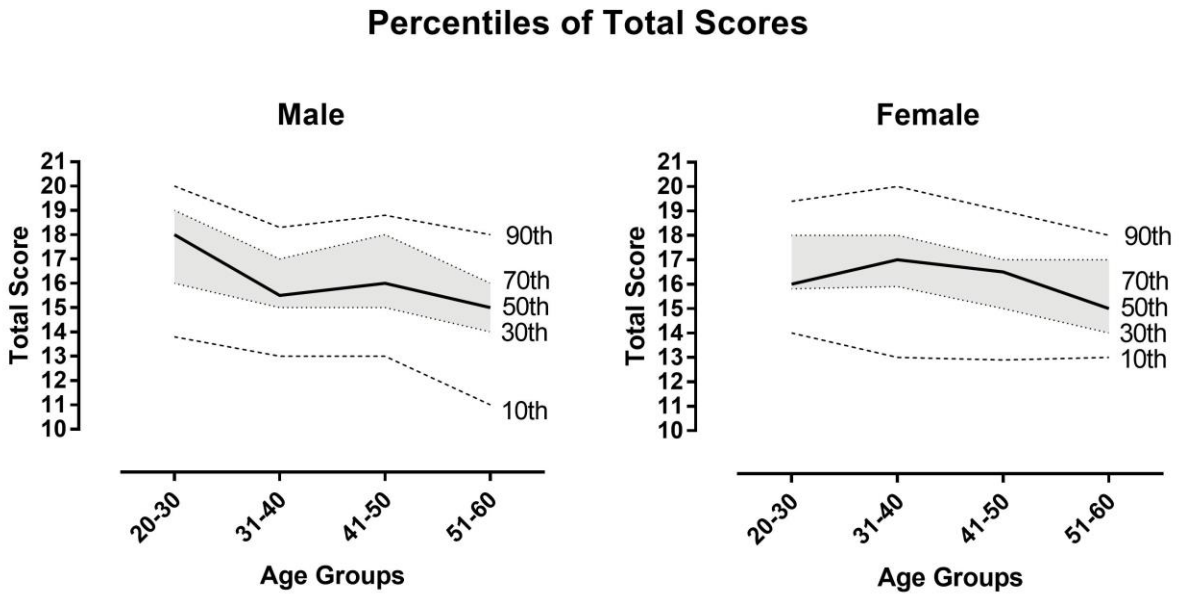

Figure 3.1: Total Scores expressed as percentiles. The 50th percentile is represented by the dark line. The shaded region between the dotted line represents the 30th to 70th percentile. The 10th to 90th is represented by the white region between the dashed lines.

3.3.2.1 Frequency Distribution of Total Scores

The 20-30 year age group had a larger frequency distribution around the higher scores, leading to a higher median (median = 17). The 51-60 year age group displayed a larger frequency distribution around the lower scores resulting in a lower median (median = 15). The frequency distribution of total scores is shown in Figure 3.2.

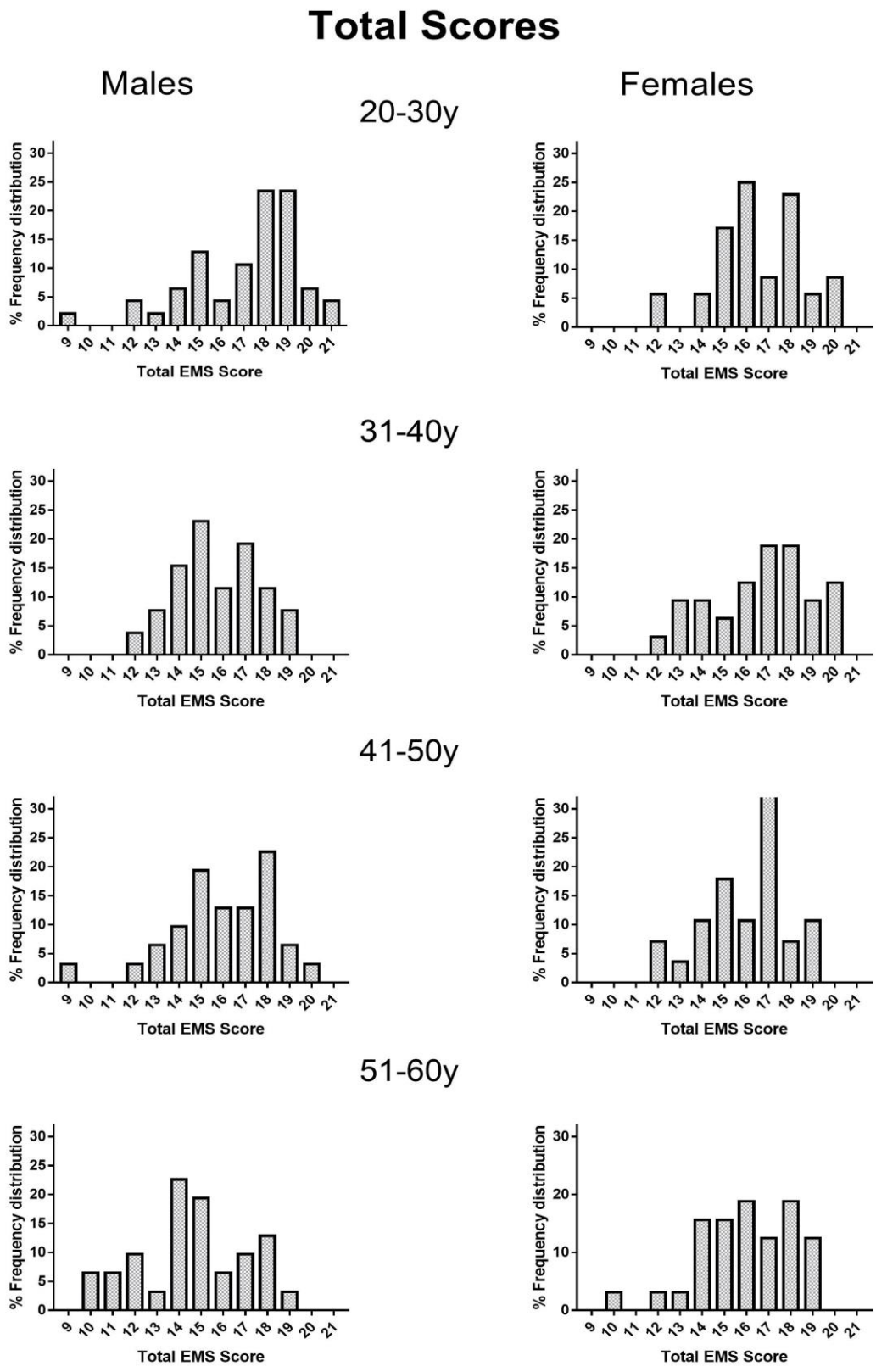

Figure 3.2 Frequency distribution of total scores across age groups.

3.3.3 Median and Interquartile Ranges

The median and interquartile range score for each of the seven tests are shown in Tables 3.6 - 3.13. Male scores are summarised in Table 3.6 - 3.9. Female scores are summarised in Table 3.10 -3.13.

The 20-30 year male group displayed similar medians across activity levels in all subtests except for the Single Leg Hurdle. The "*above recommended activity level"* subgroup displayed a higher median (Median = 3), than the less active groups in the Single Leg Hurdle component. The highest median score of three, was recorded in the Split Squat, Shoulder Mobility and Stability Push Up components. The other subtests only displayed medians of two. See Table 3.6.

Table 3.6 Median and Interquartile Range Scores for the 20-30 Year Old Males

Subtest	Activity Level	Median	25th Percentile	75th Percentile	N
Overhead Squat	**All**	**2**	**2**	**3**	**47**
	Above	2	2	3	25
	Achieved	2	2	3	12
	Below	2	2	3	10
Single Leg Hurdle	**All**	**2**	**2**	**3**	**47**
	Above	3	2	3	25
	Achieved	2	2	3	12
	Below	2	2	2	10
Split Squat	**All**	**3**	**2**	**3**	**47**
	Above	3	3	3	25
	Achieved	3	2	3	12
	Below	3	2	3	10
Shoulder Mobility	**All**	**3**	**2**	**3**	**47**
	Above	3	2	3	25
	Achieved	3	2	3	12
	Below	3	2	3	10
Asymmetric Leg Raise	**All**	**2**	**2**	**2**	**47**
	Above	2	2	3	25
	Achieved	2	1	3	12
	Below	2	2	2	10
Stability Push Up	**All**	**3**	**3**	**3**	**47**
	Above	3	3	3	25
	Achieved	3	3	3	12
	Below	3	2	3	10
Seated Rotation	**All**	**2**	**2**	**2**	**47**
	Above	2	2	2	25
	Achieved	2	2	2	12
	Below	2	1	2	10

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

The Single Leg Hurdle and Shoulder Mobility components displayed different medians across the physical activity subgroups. The "*below recommended activity level"* subgroup displayed a higher median (Median = 3), than the more active groups in the Single Leg Hurdle component. The "*above recommended activity level"* subgroup displayed a higher median (Median = 3), than the less active groups in the Shoulder Mobility component. The highest median score of three, was recorded in the Split Squat and Stability Push-up components. The other subtests recorded medians of two. See Table 3.7.

Table 3.7 Median and Interquartile Range Scores for the 31-40 Year Old Males

Subtest	Activity Level	Median	25th Percentile	75th Percentile	N
Overhead Squat	**All**	**2**	**2**	**3**	**26**
	Above	2	2	2	10
	Achieved	2	2	3	8
	Below	2	2	3	8
Single Leg Hurdle	**All**	**2**	**2**	**2**	**26**
	Above	2	2	2	10
	Achieved	2	2	2	8
	Below	3	2	3	8
Split Squat	**All**	**3**	**2**	**3**	**26**
	Above	3	2	3	10
	Achieved	3	2	3	8
	Below	3	2	3	8
Shoulder Mobility	**All**	**2**	**2**	**3**	**26**
	Above	3	2	3	10
	Achieved	2	1	3	8
	Below	2	2	2	8
Asymmetric Leg Raise	**All**	**2**	**2**	**2**	**26**
	Above	2	2	3	10
	Achieved	2	2	2	8
	Below	2	1	2	8
Stability Push Up	**All**	**3**	**3**	**3**	**26**
	Above	3	3	3	10
	Achieved	3	3	3	8
	Below	3	3	3	8
Seated Rotation	**All**	**2**	**2**	**2**	**26**
	Above	2	1	2	10
	Achieved	2	2	3	8
	Below	2	2	2	8

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

The 41-50 year male group displayed different medians across activity levels in the Overhead Squat, Split Squat and Asymmetric Leg Raise components. The "*below recommended activity level"* male subgroup, displayed a higher median (Median = 3), than the more active groups (Median = 2), in these subtests. The other subtests displayed similar medians.

The highest median score of three, was recorded in the Stability Push Up component. The other subtests recorded medians of two. See Table 3.8.

Table 3.8 Median and Interquartile Range Scores for the 41-50 Year Old Males

Subtest	Activity Level	Median	25th Percentile	75th Percentile	n
Overhead Squat	**All**	**2**	**2**	**3**	**31**
	Above	2	2	3	13
	Achieved	2	2	3	10
	Below	3	2	3	8
Single Leg Hurdle	**All**	**2**	**2**	**2**	**31**
	Above	2	2	3	13
	Achieved	2	2	2	10
	Below	2	2	3	8
Split Squat	**All**	**2**	**2**	**3**	**31**
	Above	2	2	3	13
	Achieved	2	2	3	10
	Below	3	2	3	8
Shoulder Mobility	**All**	**2**	**2**	**3**	**31**
	Above	2	2	3	13
	Achieved	2	2	3	10
	Below	2	1	3	8
Asymmetric Leg Raise	**All**	**2**	**1**	**3**	**31**
	Above	2	1	3	13
	Achieved	2	1	3	10
	Below	3	1	3	8
Stability Push Up	**All**	**3**	**3**	**3**	**31**
	Above	3	3	3	13
	Achieved	3	2	3	10
	Below	3	2	3	8
Seated Rotation	**All**	**2**	**1**	**2**	**31**
	Above	2	2	2	13
	Achieved	2	1	2	10
	Below	2	1	2	8

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

The 50-60 year male group displayed similar medians across activity levels in all subtests. The Stability Push Up component displayed the highest median (Median = 3). The other subtests displayed a median of two. See Table 3.9.

Table 3.9 Median and Interquartile Range Scores for the 51-60 Year Old Males

Subtest	Activity Level	Median	25th Percentile	75th Percentile	n
Overhead Squat	**All**	**2**	**2**	**2**	**31**
	Above	2	2	2	11
	Achieved	2	2	2	10
	Below	2	2	2	10
Single Leg Hurdle	**All**	**2**	**1**	**2**	**31**
	Above	2	1	2	11
	Achieved	2	2	2	10
	Below	2	1	2	10
Split Squat	**All**	**2**	**1**	**2**	**31**
	Above	2	1	3	11
	Achieved	2	2	3	10
	Below	2	1	2	10
Shoulder Mobility	**All**	**2**	**2**	**3**	**31**
	Above	2	2	3	11
	Achieved	2	2	3	10
	Below	2	1	2	10
Asymmetric Leg Raise	**All**	**2**	**2**	**3**	**31**
	Above	2	1	3	11
	Achieved	2	2	3	10
	Below	2	2	3	10
Stability Push Up	**All**	**3**	**2**	**3**	**31**
	Above	3	3	3	11
	Achieved	3	3	3	10
	Below	3	2	3	10
Seated Rotation	**All**	**2**	**1**	**2**	**31**
	Above	2	1	2	11
	Achieved	2	1	2	10
	Below	2	1	2	10

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

The medians of the physical activity subgroups for the 20-30 year females were similar except for the Split Squat, Asymmetric Leg Raise and Stability Push Up components (table 3.10). The "*achieved recommended activity level*" subgroup displayed a lower median (Median = 2), than the other subgroups in the Split Squat component. The "*above recommended activity level"* and "*achieved recommended activity level*" subgroups displayed a higher median (Median = 3), than the least active group in the Asymmetric Leg Raise component. The "*achieved recommended activity level*" subgroup displayed a higher median (Median = 3), than the other two subgroups in the Stability Push Up component.

Table 3.10 Median and Interquartile Range Scores for 20-30 Year Old Females

Subtest	Activity Level	Median	25th Percentile	75th Percentile	n
Overhead Squat	**All**	**2**	**2**	**3**	**35**
	Above	2	2	3	14
	Achieved	2	2	3	11
	Below	2	2	2	10
Single Leg Hurdle	**All**	**2**	**2**	**2**	**35**
	Above	2	2	2	14
	Achieved	2	2	3	11
	Below	2	2	2	10
Split Squat	**All**	**3**	**2**	**3**	**35**
	Above	3	2	3	14
	Achieved	2	3	3	11
	Below	3	2	3	10
Shoulder Mobility	**All**	**3**	**2**	**3**	**35**
	Above	3	3	3	14
	Achieved	3	2	3	11
	Below	3	2	3	10
Asymmetric Leg Raise	**All**	**2**	**2**	**3**	**35**
	Above	3	2	3	14
	Achieved	3	2	3	11
	Below	2	2	2	10
Stability Push Up	**All**	**2**	**2**	**3**	**35**
	Above	2	2	3	14
	Achieved	3	1	3	11
	Below	2	2	2	10
Seated Rotation	**All**	**2**	**2**	**3**	**35**
	Above	2	2	2	14
	Achieved	2	2	3	11
	Below	2	2	2	10

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

The highest median score of three, was recorded in the Split Squat and Shoulder Mobility components. The other subtests only recorded medians of two. See Table 3.10.

The medians of the physical activity subgroups for the 31-40 year females were similar except for the Stability Push Up component. The "*above recommended activity level*" subgroup displayed a higher median (Median = 3), than the other subgroups in this component. The Split Squat, Shoulder Mobility and Asymmetric Leg Raise components displayed the highest median of three. The other subtests recorded medians of two. See Table 3.11.

Table 3.11 Median and Interquartile Range Scores for the 31-40 Year Old Females

Subtest	Activity Level	Median	25th Percentile	75th Percentile	n
Overhead Squat	**All**	**2**	**2**	**3**	**32**
	Above	2	2	3	11
	Achieved	2	2	3	9
	Below	2	2	3	12
Single Leg Hurdle	**All**	**2**	**2**	**3**	**32**
	Above	2	2	3	11
	Achieved	2	2	3	9
	Below	2	2	2	12
Split Squat	**All**	**3**	**2**	**3**	**32**
	Above	3	3	3	11
	Achieved	3	2	3	9
	Below	3	2	3	12
Shoulder Mobility	**All**	**3**	**2**	**3**	**32**
	Above	3	2	3	11
	Achieved	3	2	3	9
	Below	3	2	3	12
Asymmetric Leg Raise	**All**	**3**	**2**	**3**	**32**
	Above	3	2	3	11
	Achieved	3	2	3	9
	Below	3	2	3	12
Stability Push Up	**All**	**2**	**2**	**3**	**32**
	Above	3	2	3	11
	Achieved	2	1	3	9
	Below	2	1	3	12
Seated Rotation	**All**	**2**	**2**	**3**	**32**
	Above	2	2	3	11
	Achieved	2	2	3	9
	Below	2	2	2	12

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

The Seated Rotation and Single Leg Hurdle displayed similar medians across physical activity subgroups, in the 41-50 year female group. The remaining five subtests had dissimilar medians.

The "*achieved recommended activity level*" subgroup displayed the highest median in the Overhead Squat component. In the Split Squat component, the "*above recommended activity level*" and b*elow recommended activity level*" subgroups displayed the highest median (median =3). In the Shoulder Mobility component, "*achieved recommended activity level*" and "*below recommended activity level*" had the highest median (median = 3).

Table 3.12 Median and Interquartile Range Scores for the 41-50 Year Old Females

Subtest	Activity Level	Median	25th Percentile	75th Percentile	n
Overhead Squat	**All**	**2**	**2**	**3**	**28**
	Above	2	2	3	9
	Achieved	3	2	3	10
	Below	2	1	2	9
Single Leg Hurdle	**All**	**2**	**2**	**2**	**28**
	Above	2	2	3	9
	Achieved	2	2	2	10
	Below	2	2	2	9
Split Squat	**All**	**3**	**2**	**3**	**28**
	Above	3	2	3	9
	Achieved	2	2	3	10
	Below	3	2	3	9
Shoulder Mobility	**All**	**3**	**2**	**3**	**28**
	Above	2	2	3	9
	Achieved	3	2	3	10
	Below	3	3	3	9
Asymmetric Leg Raise	**All**	**3**	**2**	**3**	**28**
	Above	3	3	3	9
	Achieved	2	2	3	10
	Below	3	2	3	9
Stability Push Up	**All**	**2**	**2**	**3**	**28**
	Above	3	3	3	9
	Achieved	2	2	3	10
	Below	2	2	3	9
Seated Rotation	**All**	**2**	**2**	**3**	**28**
	Above	2	2	3	9
	Achieved	2	1	2	10
	Below	2	2	3	9

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

In the Asymmetric Leg Raise component, the "*above recommended activity level*" and "*below recommended activity level*" subgroups displayed the highest median (median =3). The "*achieved recommended activity level*" subgroup displayed the highest median in the Overhead Squat component. The Split Squat, Shoulder Mobility and Asymmetric Leg Raise components had the highest median of the three, while the remaining groups had a median of two. median of three (Table 3.12).

Table 3.13 Median and Interquartile Range Scores for the 51-60 Year Old Females

Subtest	Activity Level	Median	25th Percentile	75th Percentile	n
Overhead Squat	**All**	**2**	**2**	**2**	**32**
	Above	2	2	2	10
	Achieved	2	1	2	12
	Below	2	2	2	10
Single Leg Hurdle	**All**	**2**	**1**	**2**	**32**
	Above	2	2	2	10
	Achieved	2	2	2	12
	Below	2	1	2	10
Split Squat	**All**	**2**	**2**	**3**	**32**
	Above	2	2	3	10
	Achieved	2	2	3	12
	Below	2	1	2	10
Shoulder Mobility	**All**	**3**	**2**	**3**	**32**
	Above	3	2	3	10
	Achieved	3	3	3	12
	Below	3	2	3	10
Asymmetric Leg Raise	**All**	**3**	**2**	**3**	**32**
	Above	3	3	3	10
	Achieved	3	2	3	12
	Below	3	3	3	10
Stability Push Up	**All**	**2**	**1**	**2**	**32**
	Above	2	2	2	10
	Achieved	2	1	3	12
	Below	1	1	2	10
Seated Rotation	**All**	**2**	**2**	**2**	**32**
	Above	2	2	2	10
	Achieved	2	2	2	12
	Below	2	2	2	10

Above: "above the recommended level of physical activity"
Achieved: "achieved the recommended level of physical activity"
Below: "below the recommended level of physical activity"

In the 50-60 year female group, the Stability Push Up was the only component to display dissimilar medians across physical activity subgroups (Table 3.10). The "*below recommended activity level*" subgroup had the lowest median (Median = 1), in the Stability Push Up component. This was the lowest median recorded between all age groups and genders. The other subgroups in this component had a similar median (Median = 2). The Shoulder Mobility and Asymmetric Leg Raise components displayed the highest median (Median = 3). The other components recorded medians of two (Table 3.13).

3.3.4 Frequency Distribution of Subtest Scores

3.3.4.1Overhead Squat

The Overhead Squat component had similar frequency distributions, except for the oldest group. The 51-60 old group displayed less high score frequencies throughout all activity level subgroups, than the younger age groups (Figure 3.3a).

3.3.4.2 Single Leg Hurdle

There were higher frequencies of high scores in the male group, compared to the female group. The 51-60 year group had higher frequencies of the low scores. The younger groups (20-30, 31-40 and 41-50 year groups) had higher frequencies of high scores compared to the 51-60 year group. The more active subgroups displayed higher frequencies of high scores, than the least active groups (Figure 3.3b).

3.3.4.3 Split Squat

The 20-30 year group had the highest frequency distribution of high, while the 51-60 year group had the lowest. All age groups had a similar frequency distribution for the middle score. The 51-60 year group the highest frequency of low scores. No clear pattern is seen for gender and activity level differences (Figure 3.3c).

3.3.4.4 Shoulder Mobility

Males had higher frequencies of the slow scores compared to females. Females had a higher frequency of high scores compared to males. There is no clear pattern when comparing age groups, or activity levels (Figure 3.3d).

3.3.4.5 Asymmetric Leg Raise

The males scored lower than the females in the Asymmetric Leg Raise component. The females had higher frequencies of high scores in this component (Figure 3.3e).

3.3.4.6 Stability Push Up

Males recorded higher frequencies of high scores across all age and activity level subgroups, compared to females (Figure 3.3f).

3.3.4.7 Seated Rotation

Females recorded higher frequencies of high scores in all subgroups, compared to males (Fig 3.3g).

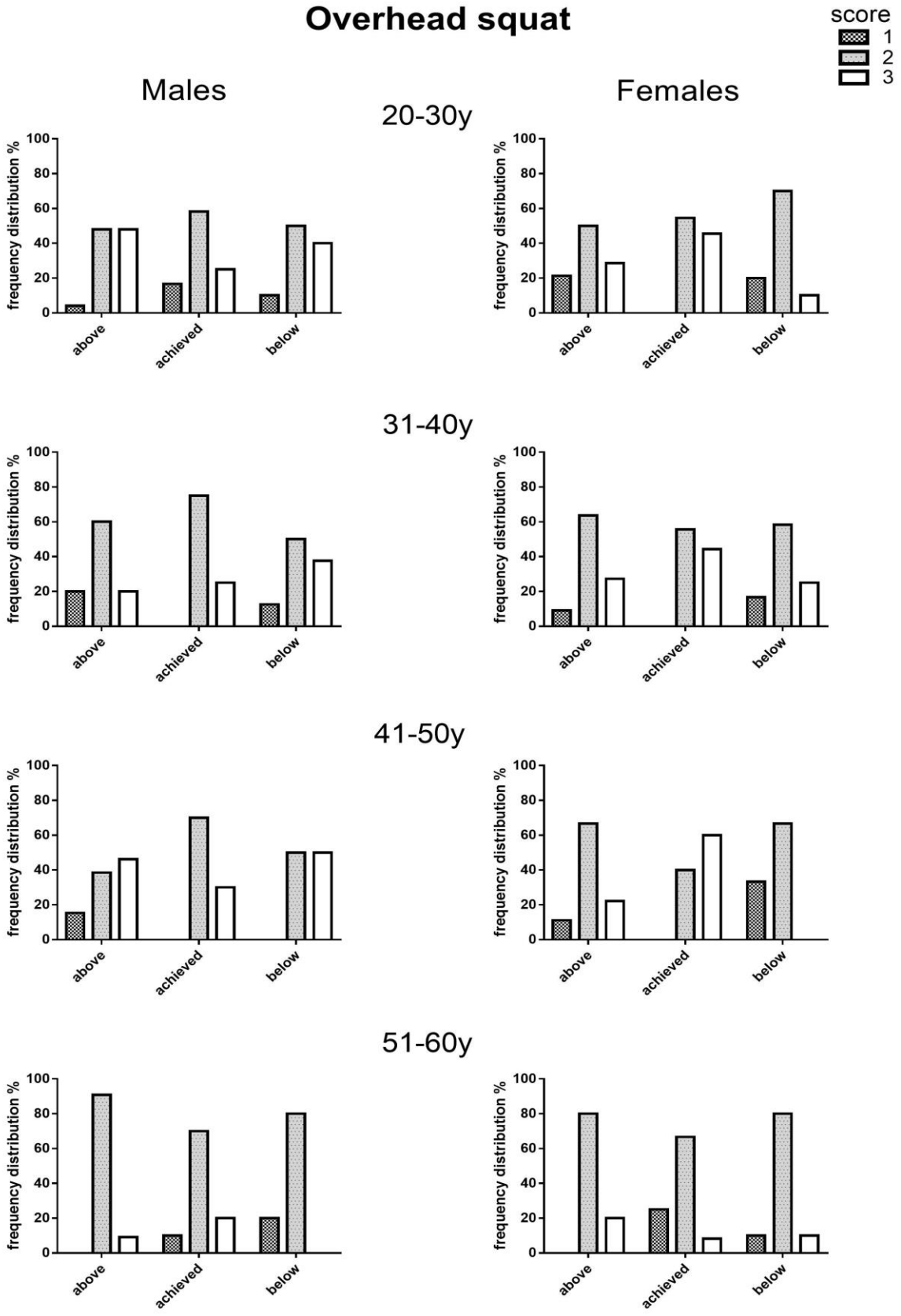

Figure 3.3a Frequency distribution of Overhead Squat scores

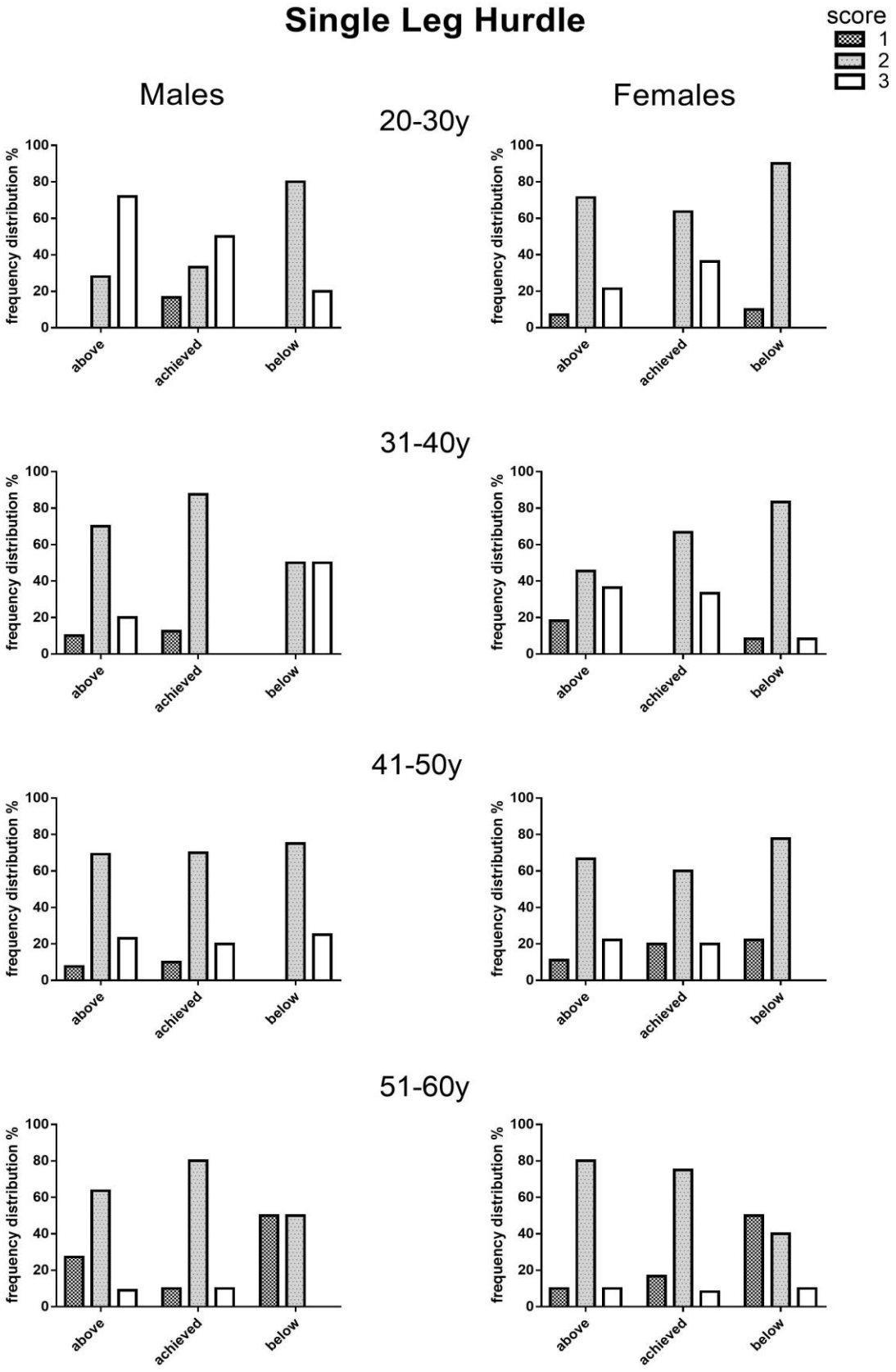

Figure 3.3b Frequency distribution of Single Leg Hurdle scores

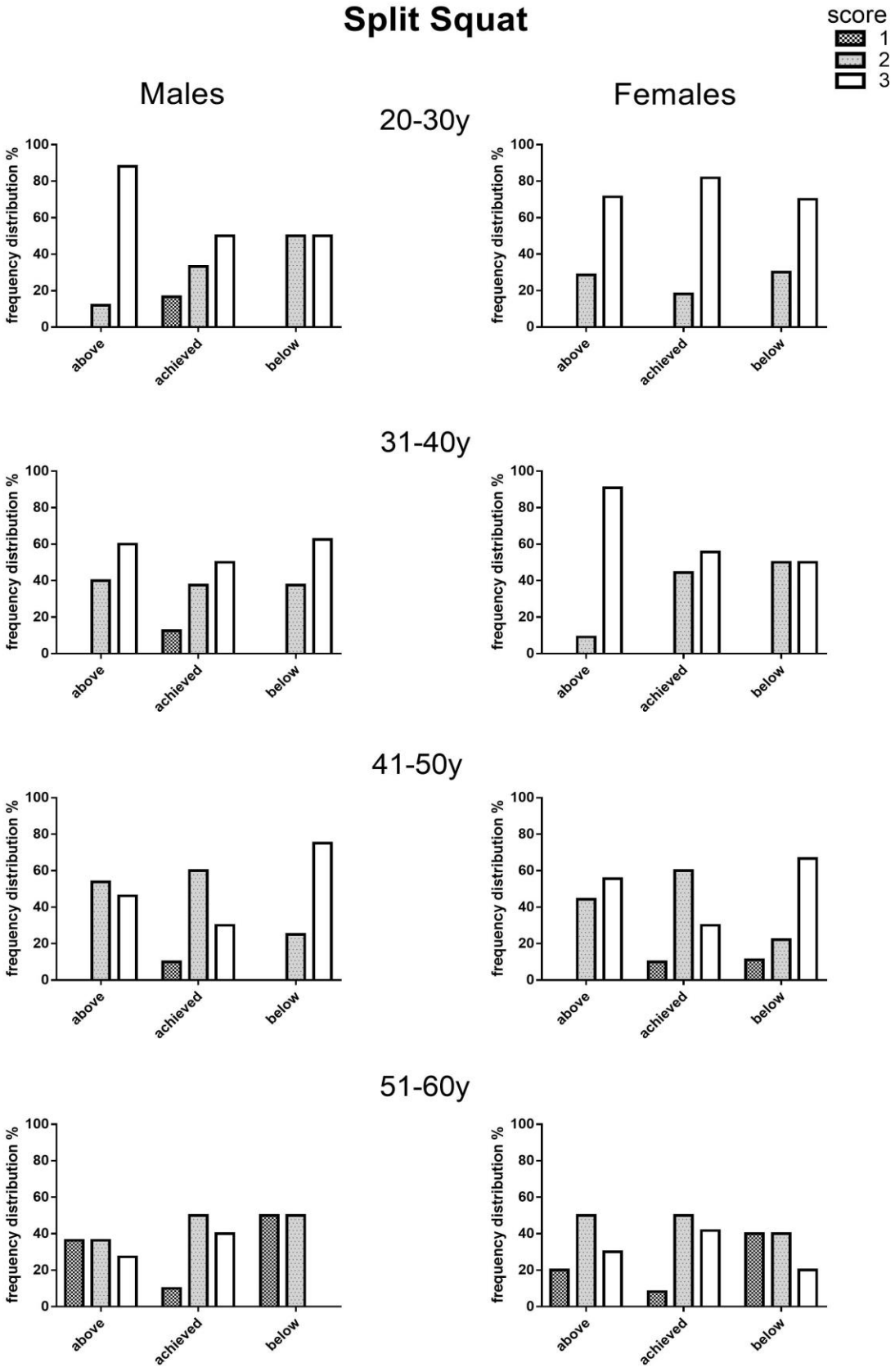

Figure 3.3c Frequency distribution of Split Squat scores

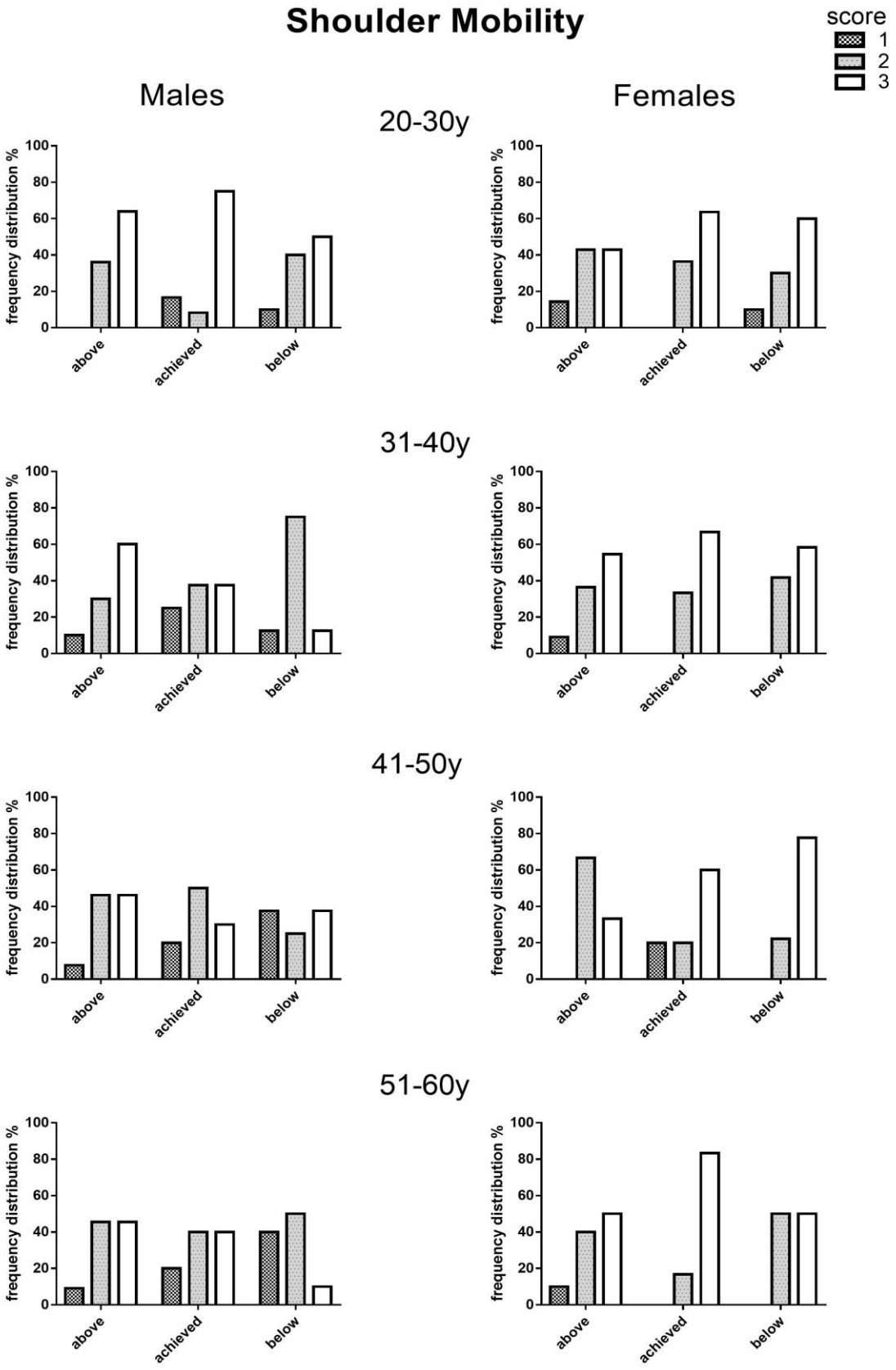

Figure 3.3d Frequency distribution of Shoulder Mobility

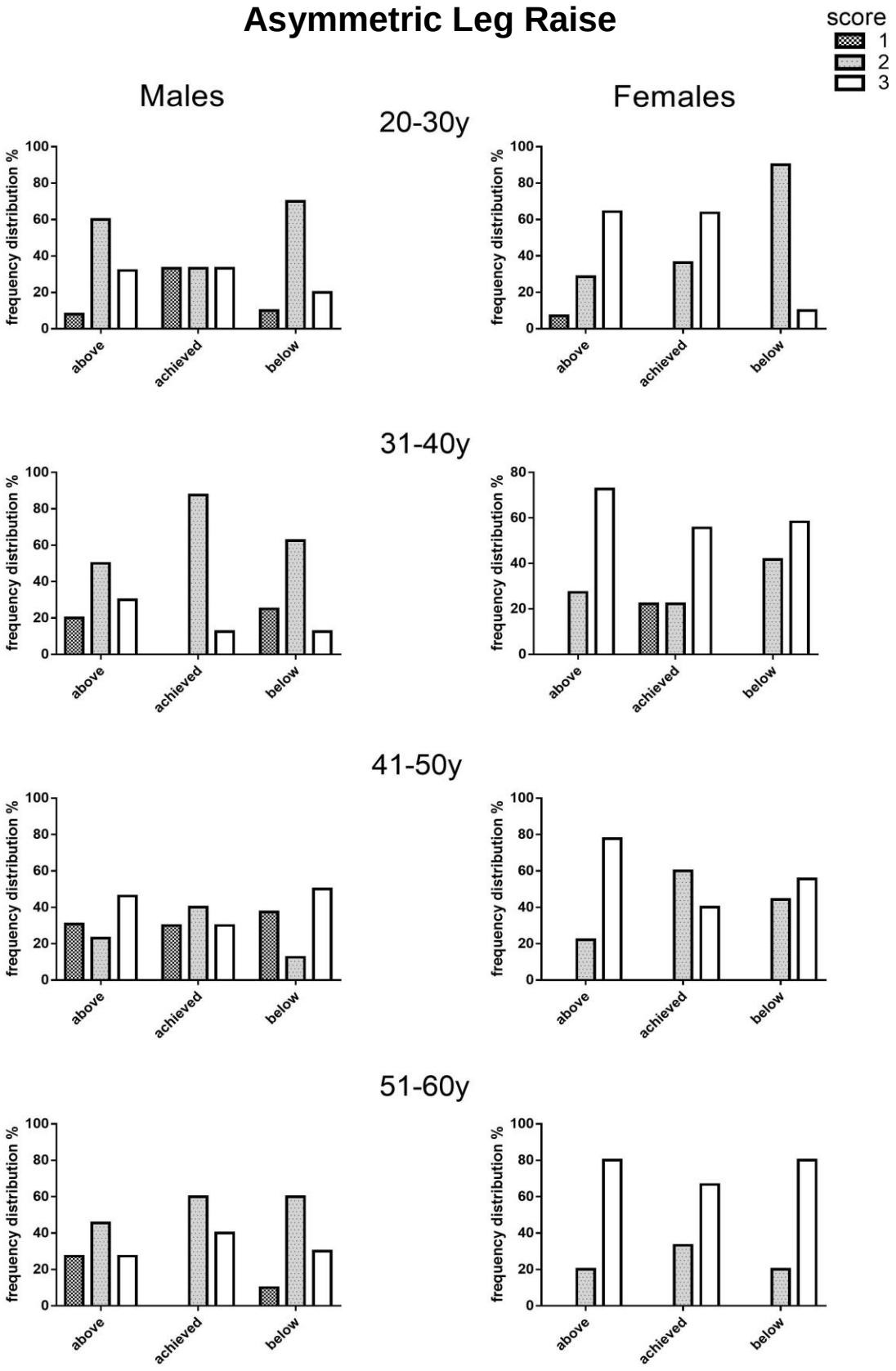

Figure 3.3e Frequency distribution of Asymmetric Leg Raise scores

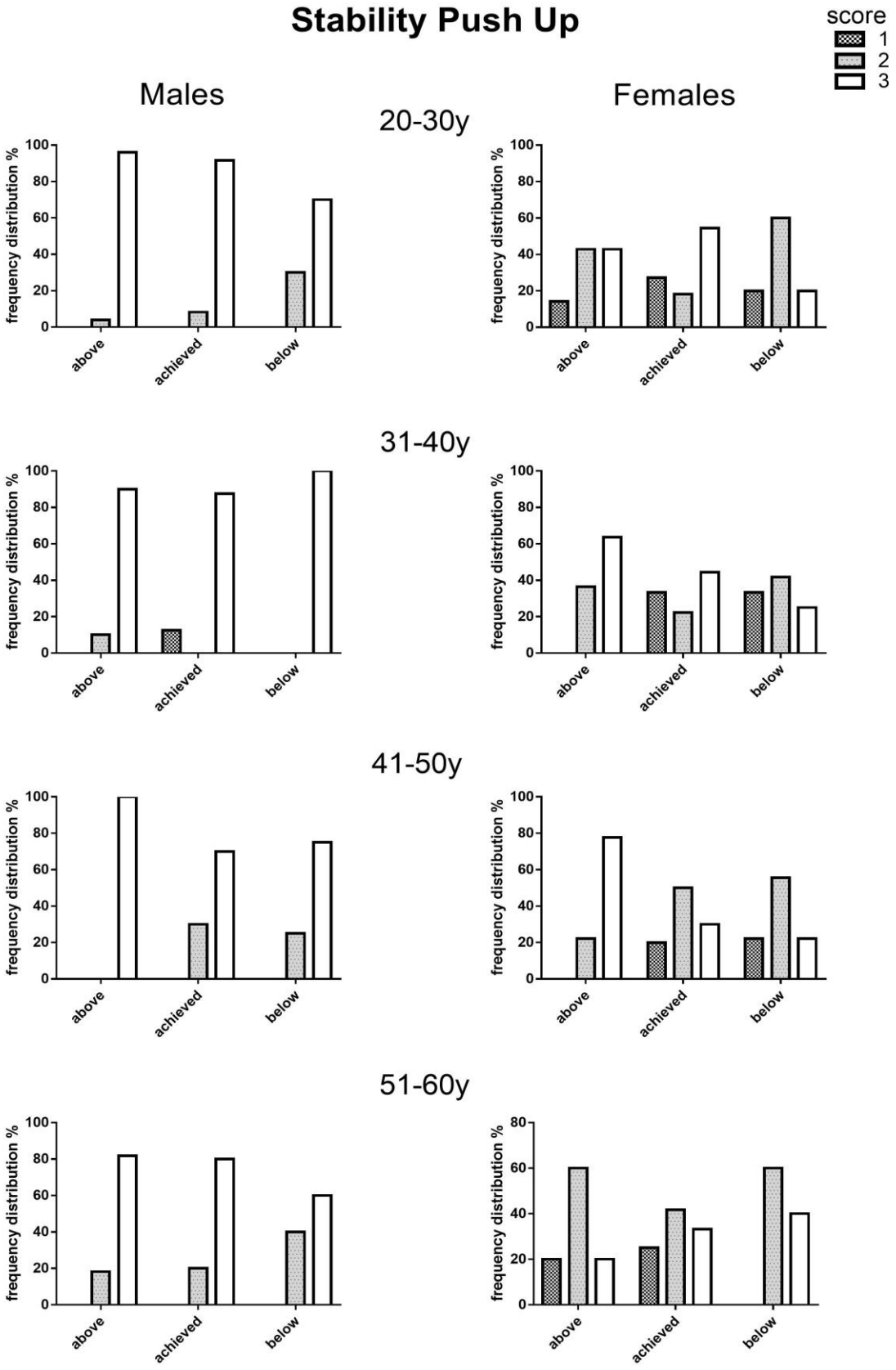

Figure 3.3f Frequency distribution of Stability Push Up scores

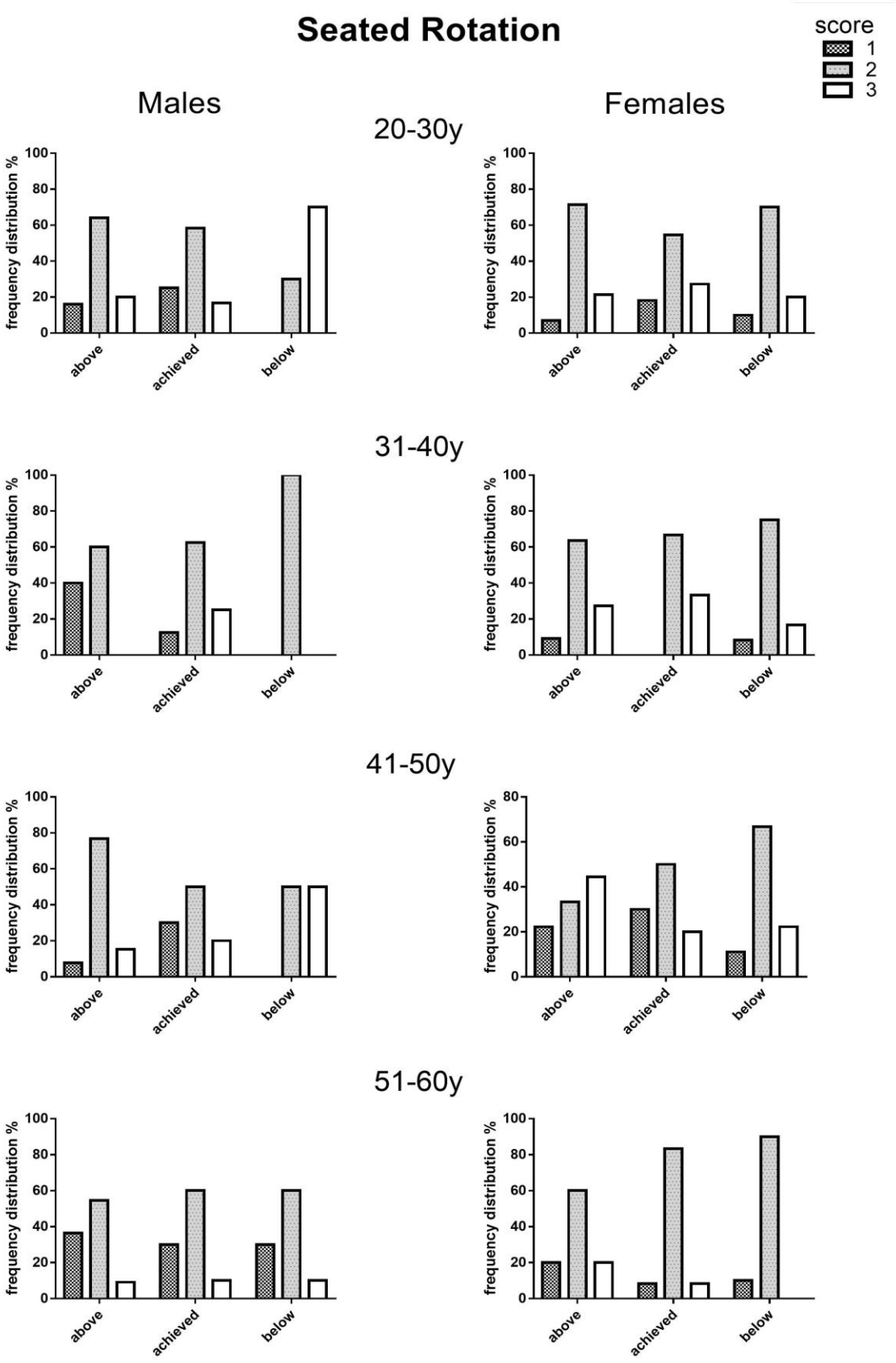

Figure 3.3g Frequency distribution of Seated Rotation scores

3.3.5 Chi square results

3.3.5.1 Overhead Squat

There was a significant association between age and the Overhead Squat scores, X^2 (6, n = 262) = 13.283, p = 0.039. In the 51-60 age group, the frequency of high scores (score = 3) was lower than expected while the middle scores (score = 2) were higher than expected. In the other groups, the observed and expected frequencies were similar.

There were no significant associations of gender [X^2 (2, n = 262) = 1.705, p = 0.426)] and activity level [X^2 (4, n = 262) = 4.991, p = 0.288] on Overhead Squat scores. The observed frequencies were similar to the expected frequencies.

3.3.5.2 Single Leg Hurdle

Gender had a significant effect on Single Leg Hurdle scores, X^2 (2, n = 262) = 6.150, p = 0.046. In the high scoring group, males had a higher than expected frequency, while females had a lower than expected frequency. Conversely, females had a higher than expected frequency among the middle scoring group, while males had a lower than expected frequency. In the low scoring group (score = 1), observed and expected frequencies were similar for both genders.

Age also had a significant effect on Single Leg Hurdle scores, X^2 (6, n = 262) = 32.897, p = 0.001. In the 20-30 age group, frequencies were lower than expected for both the lower and middle scores. Consequently, the frequency of higher scores were overexpressed. The 31-40 and 41-50 year age groups had expected frequencies across all scores. The 50-60 year age group had higher than expected frequencies among the low scores, while their high score frequency was lower than expected.

The activity level of participants had a significant effect on the Single Leg Hurdle scores, X^2 (4, n = 262) = 11.189, p = 0.025. The most active group ("*above the recommended activity level*") had higher than expected frequencies in the high scoring group and lower than expected frequencies for the middle and low scores. The expected and observed frequencies were similar in the "*achieved the recommended activity level*" group. The least active group ("*below the recommended activity level*") had higher frequencies than expected among the low and middle scores, while the high score frequencies were lower than expected.

3.3.5.3 Split Squat

There were no significant associations of gender [X^2 (2, n = 262) = 1.014, p = 0.602)] and activity level [X^2 (4, n = 262) = 7.387, p = 0.117] on Split Squat scores. The observed and expected frequencies where similar.

There was a significant association between age and Split Squat scores, X^2 (6, n = 262) = 51.584, p = 0.001. The frequency of high scores were higher than expected in the 20-30 year age group. This group also had lower than expected frequencies in the middle and low scoring group. The 31-40 year age group had higher than expected frequencies among the high scores, while the low score frequency was less than expected. The observed frequency was similar to the expected in the middle scoring group. The 41-50 year age group had similar observed and expected frequencies across all scores. The 50-60 year age group had higher than expected frequencies among the low scores and middle scores, while their high score frequency was lower than expected.

3.3.5.4 Shoulder Mobility

Gender had a significant association with Shoulder Mobility scores, X^2 (2, n = 262) = 11.858, p = 0.002. In the high scoring group, females had a higher than expected frequency while males had a lower than expected frequency. Males had a higher than expected frequency in the middle and low scoring groups. Conversely, females had a lower than expected frequency in both the middle and low scoring groups.

There were no significant associations of age [X^2 (6, n = 262) = 8.653, p = 0.194)] and activity level [X^2 (4, n = 262) = 7.253, p = 0.123] on Split Squat scores. The observed and expected frequencies where similar.

3.3.5.5 Asymmetric Leg Raise

Gender had a significant effect on Asymmetric Leg Raise scores, X^2 (2, n = 262) = 31.199, p = 0.001. Females had a higher than expected frequency, while males had a lower than expected frequency in the high scoring group. Males had a higher than expected frequency in the middle and low scoring groups. Females had a lower than expected frequency in the middle and low scoring groups.

There were no significant associations of age [X^2 (6, n = 262) = 8.712, p = 0.190)] and activity level [X^2 (4, n = 262) = 3.036, p = 0.552] on Split Squat scores. The observed and expected frequencies where similar.

3.3.5.6 Stability Push Up

Gender had a significant association with Stability Push Up scores, X^2 (2, n = 262) = 70.865, p = 0.001. Males had a higher than expected frequency, while females had a lower than expected frequency in the high scoring group. Males had lower than expected frequency in the middle and low scoring groups. Females had a higher than expected frequency in the middle and low scoring groups.

The activity level of participants also had a significant effect on the Stability Push Up scores, X^2 (4, n = 262) = 20.287, p = 0.001. The most active group had higher than expected frequencies in the high scoring group. This group also had lower than expected frequencies for the middle and low scores.

The "*achieved recommended activity level*" group had frequencies similar to the expected across all scores. The least active group had higher frequencies than expected among the low and middle scores. Consequently, the high score frequencies were lower than expected for this group.

Age had no significant association with Stability Push Up scores, X^2 (6, n = 262) = 10.768, p = 0.096. The observed and expected frequencies where similar.

3.3.5.7 Seated Rotation

Gender had a significant effect on the Seated Rotation component, X^2 (2, n = 262) = 8.499, p = 0.014. The frequency was higher than expected for Females and lower than expected for males, in the high scoring group. Both genders had expected frequencies in the middle scoring group. In the low scoring group, males had a higher than expected frequency while females had a lower than expected frequency.

There were no significant associations of age [X^2 (6, n = 262) = 6.143, p = 0.379)] and activity level [X^2 (4, n = 262) = 4.648, p = 0.325] on Split Squat scores. The observed and expected frequencies where all similar.

The Chi square results are summarised in Table 3.14. Calculations for the statistics can be viewed in Appendix VI.

Table 3.14 Summary of Pearson Chi Square Results

Subtest	Sex* Df = 2	Age Group* Df = 6	Activity Level* Df = 4
Overhead Squat	0.426	**0.039**	0.288
Single Leg Hurdle	**0.046**	**0.001**	**0.025**
Split Squat	0.602	**0.001**	0.117
Shoulder Mobility	**0.002**	0.194	0.123
Asymmetric Leg Raise	**0.001**	0.190	0.552
Stability Push Up	**0.001**	0.096	**0.001**
Seated Rotation	**0.014**	0.379	0.325

* Asymptotic Significance (2-Sided)
Df = Degrees of Freedom

3.4 DISCUSSION

3.4.1 Descriptive statistics

The study used a sample of 262 participants (Male; n = 135; Female; n = 127), which was divided into smaller subgroups of gender, age and physical activity level. The average age of males was 39 ± 12 years while females had an average age of 40 ± 11 years. Both the male and female groups had an average BMI of 25. This is one of the few studies to include a large sample of participants over a wide range of ages and different physical activity backgrounds. The large sample size allowed for homogenous subgroups to be formed (Table 3.4a & 3.4b).

3.4.2 Total Scores

Age had a negative association with total scores, when genders were combined. The younger groups displayed higher scores than the older groups. The 20-30 and 31-40 year groups displayed the highest median of 17. The 41-50 and 51-60 year groups displayed medians of 16 and 15, respectively. There was a linear decline in scores from the 31-40 to the 51-60 year age groups. This finding agrees with the results of previous studies (Koehle et al., 2016; Mitchell et al., 2016; Perry & Koehle, 2013)

There was also a clear pattern among male groups. The youngest male group (20-30 year) displayed the highest median of 18. The 31-40 and 41-50 year male groups displayed the same median of 16. As expected, the 51-60 year group displayed the lowest median of 15. The pattern was not as clear among females. Interestingly the two middle aged female groups of 31-40 and 41-50 years displayed the highest median score of 17. The youngest (20-30 years) group only displayed a median of 16 which is lower than the two middle groups. It was expected that the younger groups will score higher than the older groups. The lower total scores among the younger females may be explained by their increased joint laxity and decreased stability. Younger age is associated with increased flexibility (Baudry, 2016; Daley & Spinks, 2000). Increased flexibility and joint laxity may increase injury risk and cause lower performance in activities with low loading rates (E Witvrouw et al., 2011). The EMS components entail slow controlled movements and therefore the younger participants may have a disadvantage due to decreased control. The oldest (51-60 years) group had the lowest median of 15. The oldest groups (51-60 year old) displayed the lowest total score regardless of gender. There was no consistent pattern between the 20-50 year ages when male and female age groups were compared side to side. This could indicate that ages between 20-50 years is not a major factor, but ages older than 50 is.

3.4.3 Subtest Scores

Gender, age and activity levels have a clear association with the subtests of the EMS. The associations will be discussed under the relevant headings.

3.4.3.1 Gender

Gender was the factor that affected the most subtests. All EMS subtests except the Overhead Squat and Split Squat had a significant association with gender. Males scored significantly higher in the Single Leg Hurdle and Stability Push Up components than females. These two components are associated with strength and control. The literature has shown that men have higher levels of stability and strength and therefore it may explain their superior scoring in these components (Blackburn, Riemann, Padua, & Guskiewicz, 2004; Lindle et al., 1997; Myer et al., 2013; Stoll et al., 2000)

Females scored significantly higher in the Asymmetric Leg Raise, Shoulder Mobility and Seated Rotation components than males. These tests assess flexibility and mobility as opposed to strength. The higher scores among females may be explained by the fact that females have higher levels of flexibility compared to men (Granata, Wilson, & Padua, 2002; Intolo et al., 2009; Teyhen et al., 2014)

Males scored higher than females in the components associated with control and strength. This may be due to males generally being stronger than females (Lindle et al., 1997). Females scored higher in the mobility components, which agrees with the findings that females have higher levels of flexibility (Chung, 2009; Soucie et al., 2011).

3.4.3.2 Age

Age had a significant association with three subtests. The Overhead Squat, Single Leg Hurdle and Split Squat components were all affected by the age of participants. The 20-30 year group had the highest scores in the Single Leg Hurdle and Split Squat components. The 20-30 and 41-50 year groups had the combined highest score in the Overhead Squat component. Interestingly, the 41-50 group scored higher than the younger 31-40 year group, in the Overhead Squat component. The 51-60 year group had the lowest scores in all three subtests (Overhead Squat, Single Leg Hurdle and Split Squat). This is in accordance with the findings of previous studies (Agresta et al., 2014; Koehle et al., 2016; Mitchell et al., 2016; Perry & Koehle, 2013). This may be attributed to the tests being associated with balance and control, which decreases with aging (Baudry, 2016). The poor performance in these components could also be due to the effects of sarcopenia associated with older age (Daly et al., 2013; Nakano et al, 2014). Interestingly, there was no significant association with older age and the flexibility components (Shoulder Mobility, Asymmetric Leg Raise, Trunk Rotation), which is contrary to the expected.

3.4.3.3 Physical Activity Level

Activity levels had a significant association with The Single Leg Hurdle and Stability Push Up components. The "*above recommended activity level*" subgroup had the highest scores in both subtests. Conversely, the "*below recommended activity level*" subgroup displayed the lowest scores.

The Single Leg Hurdle and Stability Push Up components are associated with control and strength. The more physically active groups scored the highest. This may be due to the positive effects of increased physical activity, which could improve balance and strength in these individuals (Lee et al., 2012; Nunan et al., 2013).

3.5 CONCLUSION

In conclusion, the study confirmed that the gender, age and physical activity levels have clear associations with EMS scores. Gender is the most important variable as it had a significant effect on five subtests. Males scored higher in the strength and control components, while females scored higher in the flexibility components. Age influenced three subtests. Although the scoring pattern is not clear between the 20-50 year age groups, the 51-60 old group consistently scored the lowest in all three of the affected subtests. Age only seems to affect subtests associated with strength and control, and not flexibility. Only two subtests were significantly affected by physical activity, and both were associated with strength and control.

Gender alone, does not have a significant association with total scores. When the genders are combined the youngest group scored the highest total score (median = 17) and the oldest group had the lowest score (median = 15). However, total scores do not give a clear picture of the individual's performance in the EMS, as subtest scores can vary greatly.

Finally, the heterogeneous sample is representative of a broad section of the population and therefore may be used as normative reference data. However, it is recommended that subtest scores, rather than the total scores, are used for identification of possible deficiencies.

CHAPTER FOUR

SUMMARY AND CONCLUSION

4.1 Summary

Muscle, joint and bone injuries affect mobility and stability, which in turn limits physical activity (McCall et al., 2015). Screening tests are used to assess an individual's mobility and stability to determine if any movement dysfunctions exist. Screening tests aim to establish an individual's injury risk with the goal of guiding an intervention program (Cook et al, 2014).

The Evaluation of Mobility Screen (EMS) is a screening test that has been developed at the Sports Science Institute of South Africa. The EMS has been adapted from the FMS by exchanging the Rotatory Stability test for the Seated Rotation test. The current use of screening tools is limited due to a lack of normative datasets that establish clear associations between age, gender and physical activity levels. Most current published data are from athletes or younger populations. These data sets do not represent the general population which has variation in age, gender and physical activity levels. Therefore, there is a need to establish the relationship between screening outcomes and variables such as age, gender and physical activity level.

This led to the aim of this study which was to describe associations of different variables such as age, gender and physical activity with EMS scores. The data of this study may also provide reference values for males and females in the general population over a broad spectrum of ages, and level of physical activity.

4.2 Conclusion

This study showed that gender, age and physical activity levels have clear associations with EMS scores. All subtests of the EMS were affected by one or more factors. Gender had the biggest impact, as it had a significant association with five of the subtests (Single Leg Hurdle, Shoulder Mobility, Asymmetric Leg Raise, Stability Push Up and Seated Rotation). Females generally scored higher in the mobility components, while males generally scored better in the strength components. Age had a significant association with three subtests. The 51-60 year group, had significantly lower scores than the younger groups in the Overhead Squat, Single Leg Hurdle and Split Squat components. These three subtests are all related to strength and control (Cook et al., 2014). Interestingly, older age did not have a significant association with the mobility components as found in previous studies (Mitchell et al., 2016; Perry & Koehle, 2013). Physical activity levels had a significant association with only two subtests (Single Leg Hurdle and Stability Push Up). The *"above recommended activity level"* subgroup scored the highest, while the *"below recommended activity level"* subgroup scored the lowest, in these two subtests.

These results indicate that gender, age and physical activity levels should be considered when analysing and interpreting EMS scores. Even though the total score values could be similar between different individuals, the component scores may differ among the subtests. This is important when making assumptions and recommending corrective exercise based on EMS outcomes.

4.3 Recommendations for Practical Application

There has been mounting criticism for using total scores of functional screening tools, as a measurement for injury risk (Bakken et al., 2017; Moran et al., 2017; Newton et al., 2017). With research indicating a strong association between age and total scores (Koehle et al., 2016; Mitchell et al., 2016; Perry & Koehle, 2013), the use of cut-off scores to predict injury should be reconsidered. The same cut-off scores cannot be used in all populations. This is made clear by the negative association between age and total scores, and the variation of subtest scores among genders. It suggests that total scores should not be used to measure injury risk.

Total scores may however still be useful to flag an individual if the scores are lower than expected for the specific population. If the individual's total score is in the lower spectrum of their subgroup, it may indicate a need for a closer look at the specific subtest scores. From there, a more comprehensive evaluation can be performed to assess if there is any reason for concern. Clinicians can also use the subtest scores to identify a potential limitation. However, they will need to use clinical reasoning and evidence-based practice to find the underlying cause and assess if it is normal or not. The subtest scores may also be used as outcome measures, to track changes over time following an intervention as shown by Basar et al. (2018).

In conclusion, there are multiple variables that may affect the outcome of functional movement screenings. Age, gender and physical activity level are three of the possibilities. The observational design of this study has shown a clear association between these three variables and EMS scores. Clinicians should exercise caution when using total scores as a singular measurement. The results for this study suggest all possible subtest scores should be considered before a problematic score is identified.

4.3 Potential Limitations

This study was focussed on a South African population which may make the results specific to this sample. This study had an observational descriptive design. Therefore, cause-and-effect relationships between variables cannot be determined. The authors can only make recommendations on the associations between variables and the scores. The EMS uses a quantitative scoring system to assess functional movement. It therefore lacks the ability to make qualitative comparisons to identify individual-specific movement

strategies. Therefore, it is difficult to make inferences or draw qualitative comparisons on the differences in scores between groups. Physical activity levels were measured by a self-reported questionnaire (GPAQ). Although the GPAQ has been validated, it is dependent on the compliance of the participants in reporting their physical activity accurately.

4.4 Future Research

This study falls into the third stage of the TRIPP model (development of screening tools), as it has produced normative data and described associations between various intrinsic factors that may improve the application and interpretation of results. Future research could use the EMS as a baseline measurement and assess injury incidence through a longitudinal follow up study. Another option may be to issue corrective exercises based on the EMS findings and assess score improvements and injury incidences. Further investigation is required to clarify the relationships between other variables such as previous injury and the subtest scores.

CHAPTER FIVE

REFERENCES & APPENDICES

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Appendices

Appendix I – Ethical Approval of Initial Study

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences
Faculty of Health Sciences Human Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
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12 April 2013

HREC REF: 161/2013

Ms L Huchu
c/o Prof M Lambert
Sports Science Institute
Newlands

Dear Ms Huchu

PROJECT TITLE: THE ASSOCIATION BETWEEN CARDIORESPIRATORY FITNESS AND PERFOMANCE IN A SUBMAXIMAL STEPPING TEST STANDARDISED FOR ENERGY EXPENDITURE.

Thank you for addressing the issues raised by the Human Research Ethics Committee.

It is a pleasure to inform you that the HREC has **formally approved** the above mentioned study.

Approval is granted for one year till the 15 April 2014.

Please submit a progress form, using the standardised Annual Report Form, if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

Please add the UCT no fault insurance clause to the I/C Document.)
No Fault Clinical Trials Insurance
The University of Cape Town carries a No Fault Clinical Liability policy for participants who suffer a research-related injury in researcher-initiated clinical research:
http://www.health.uct.ac.za/usr/health/research/hrec/forms/No_Fault_2012.PDF

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

sAriefdien

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.

The Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

sAriefdien

Appendix II – Ethical Approval of Current Study

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

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10 March 2017

HREC REF: 152/2017

Prof M Lambert
Human Biology
Exercise Science & Sports Medicine
Sports Science Institute

Dear Prof Lambert

PROJECT TITLE: ESTABLISHING ASSOCIATIONS FOR THE EMS IN AN ADULT SOUTH AFRICAN POULATION-(M.PHIL-candidate-M Brink) sub-study linked to 161/2013

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30th March 2018.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the student M Brink will be involved in this study.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI),and Declaration of Helsinki (2013) guidelines.
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Appendix III – Global Physical Activity Questionnaire (GPAQ)

Global Physical Activity Questionnaire
(GPAQ)

Department of Chronic Diseases and Health Promotion
Surveillance and Population-Based Prevention
World Health Organization
20 Avenue Appia, 1211 Geneva 27, Switzerland
For further information: www.who.int/chp/steps

Global Physical Activity Questionnaire (GPAQ)

Overview

Introduction

The Global Physical Activity Questionnaire was developed by WHO for physical activity surveillance in countries. It collects information on physical activity participation in three settings (or domains) and sedentary behaviour. These domains are:

- Activity at work
- Travel to and from places
- Recreational activities

Using GPAQ

All the questions must be asked if you are using GPAQ, skipping questions or removing any of the domains will restrict the results that you are able to calculate.

Prior to using GPAQ you should review the question by question section. This section, which follows the actual questions, will guide the interviewer in asking the questions and recording responses.

GPAQ version 1

This document provides information on version 2 of the Global Physical Activity Questionnaire. It is advised that you use version 2 of GPAQ.

If you have already used GPAQ 1 and need advise on analyzing this information please refer to GPAQ version 1 section of this document.

Calculating and cleaning physical activity data

There is an analysis section at the end of this document which describes how to clean and analyze the physical activity data. This section uses the coding column as a reference for all the calculations

METs

METs are commonly used in the analysis of physical activity.

MET (Metabolic Equivalent): The ratio of the work metabolic rate to the resting metabolic rate. One MET is defined as 1 kcal/kg/hour and is equivalent to the energy cost of sitting quietly.
A MET is also defined as oxygen uptake in ml/kg/min with one MET equal to the oxygen cost of sitting quietly, around 3.5 ml/kg/min.

Coding column for questionnaire

The coding column is used as a guide for analysis of the physical activity data. If you insert this questionnaire into another questionnaire, you may change the question numbers, but do not change the coding column.

Physical Activity

Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person.

Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.

Questions		Response	Code
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work*] for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days ⌊__⌋	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads*] for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days ⌊__⌋	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. [insert other examples if needed]			
7	Do you walk or use a bicycle (*pedal cycle*) for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days ⌊__⌋	P8
9	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P9 (a-b)
Recreational activities			
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms].			
10	Do you do any vigorous-intensity sports, fitness or recreational (*leisure*) activities that cause large increases in breathing or heart rate like [*running or football,]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 13*	P10
11	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational (*leisure*) activities?	Number of days ⌊__⌋	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P12 (a-b)

Physical Activity (recreational activities) contd.			
Questions		**Response**	**Code**
13	Do you do any moderate-intensity sports, fitness or recreational *(leisure*) activities that causes a small increase in breathing or heart rate such as brisk walking,(*cycling, swimming, volleyball)*for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities?	Number of days ⌊__⌋	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day?	Hours : minutes ⌊__⌋ : ⌊__⌋ hrs mins	P15 (a-b)
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
16	How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes ⌊__⌋ : ⌊__⌋ hrs min s	P16 (a-b)

GPAQ Question by Question Guide

CORE: Physical Activity

Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. There are various domains of activity which need to be included; work, activities in and around the home and garden, to get from place-to-place (transport-related) and recreation (discretionary or leisure-time) exercise or sports activities. This opening statement **should not** be omitted.

The respondent will have to think first about the time she/he spends doing work. Work includes things that he/she has to do such as paid or unpaid work, household chores, harvesting food, fishing or hunting for food, seeking employment. [Insert other examples if needed]

In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.

	Questions	Response	Code
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work*] for at least 10 minutes continuously? *Activities are regarded as vigorous intensity if they cause a large increase in breathing and/or heart rate.* *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work? *"Typical week" means a week when a person is doing vigorous intensity activities and not an average over a period* *Valid responses range from 1-7.*	Number of days ⌊__⌋	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day? *Think of one day you can recall easily. Consider only those activities undertaken continuously for 10 minutes or more. Probe very high responses (over 4 hrs) to verify*	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads*] for at least 10 minutes continuously? *Activities are regarded as moderate intensity if they cause a small increase in breathing and/or heart rate.* *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work? *Valid responses range from 1-7*	Number of days ⌊__⌋	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day? *Think of one day you can recall easily. Consider only those activities undertaken continuously for 10 minutes or more. Probe very high responses (over 4 hrs) to verify*	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P6 (a-b)
Travel to and from places			
	The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. [insert other examples if needed] *The introductory statement to the following questions on transport-related physical activity is very important. It asks and helps the participant to now think about how they travel around getting from place-to-place. This statement **should not** be omitted.*		
7	Do you walk or use a bicycle (*pedal cycle*) for at least 10 minutes continuously to get to and from places? *Circle the appropriate response*	Yes 1 No 2 *If No, go to P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places? *Valid responses range from 1-7*	Number of days ⌊__⌋	P8

9	How much time do you spend walking or bicycling for travel on a typical day? *Think of one day you can recall easily. Consider the total amount of time walking or bicycling for trips of 10 minutes or more. Probe very high responses (over 4 hrs) to verify.*	Hours : minutes ⌊_⌊_⌋ : ⌊_⌊_⌋ hrs mins	P9 (a-b)
Recreational activities			
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure),[insert relevant terms]. *This introductory statement directs the participant to think about recreational activities. This can also be called discretionary or leisure time. It includes sports and exercise but is not limited to participation competitions. Activities reported should be done regularly and not just occasionally. It is important to focus on only recreational activities and not to include any activities already mentioned. This statement* ***should not*** *be omitted.*			
10	Do you do any vigorous-intensity sports, fitness or recreational (*leisure*) activities that cause large increases in breathing or heart rate like [*running or football,*] for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)* ? *Activities are regarded as vigorous intensity if they cause a large increase in breathing and/or heart rate.*	Yes 1 No 2 *If No, go to P 13*	P10
11	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational (*leisure*) activities? *Valid responses range from 1-7*	Number of days ⌊_⌋	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day? *Think of one day you can recall easily. Consider the total amount of time doing vigorous recreational activities for periods of 10 minutes or more. Probe very high responses (over 4 hrs).*	Hours : minutes ⌊_⌊_⌋ : ⌊_⌊_⌋ hrs mins	P12 (a-b)
13	Do you do any moderate-intensity sports, fitness or recreational *(leisure*) activities that causes a small increase in breathing or heart rate such as brisk walking,(*cycling, swimming, volleyball*)for at least 10 minutes continuously? *Activities are regarded as moderate intensity if they cause a small increase in breathing and/or heart rate.* *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities? *Valid responses range from 1-7*	Number of days ⌊_⌋	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day? *Think of one day you can recall easily. Consider the total amount of time doing moderate recreational activities for periods of 10 minutes or more. Probe very high responses (over 4 hrs).*	Hours : minutes ⌊_⌊_⌋ : ⌊_⌊_⌋ hrs mins	P15 (a-b)
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
16	How much time do you usually spend sitting or reclining on a typical day? *Consider total time spent at work sitting, in an office, reading, watching television, using a computer, doing hand craft like knitting, resting etc. Do not include time spent sleeping.*	Hours : minutes ⌊_⌊_⌋ : ⌊_⌊_⌋ hrs min s	P16 (a-b)

Cleaning GPAQ data

Introduction

It is important to standardize the way in which the data collected in cleaned and analyzed. Use the guidelines below when cleaning and analyzing your data.

The cleaning and analysis guidelines use the coding column in the questionnaire as an identifier.

Cleaning

You should clean each domain independently. Some of the calculations use all the domains and others use only one of the domains. If a participant does not respond to one of the domains it does not mean that rest of the domains are invalid.

Check for the following for all the domains.

If…	Then…
Days per week or time per day variables are missing	Case should not be included in the denominator of the domain variable
Hour values are 15, 30, 45, or 60	Move them into the corresponding minute variable, if the corresponding minute variable is empty or zero (most likely a data recording error).

Note: Cleaning each domain independently may result in a floating denominator.

Maximum values

There are no restrictions within the time variables. The only requirement is that the values are plausible.

If the sum of P3, P6, P9, P12, and P15 is greater than 24 hours or 1440 minutes then remove the respondent from all the physical activity analysis.

Note: For information on how to create P3, P6, P9, P12, and P15 see the Cleaning GPAQ with Epi Info

Detailed cleaning instructions

There are detailed cleaning instructions on how to clean each variable in the Cleaning GPAQ with Epi Info section of this document. This section includes details on how to clean the variables and the associated Epi Info code.

GPAQ 1

Introduction

GPAQ 1 is the first version of the Global Physical Activity Questionnaire. A reliability and validity study was conducted on GPAQ1 and the questionnaire was modified according to the results.

GPAQ 1 can be analyzed in the same manner as GPAQ 2. Prior to using the analysis guidelines or the STEPS generic analysis syntax, some of the variables in GPAQ 1 need to be recoded.

Changes from GPAQ 2

GPAQ 2 has removed three questions from GPAQ 1. Two of the questions are filtering questions and one looks at the length of workdays. These three questions are:

- GPAQ1P1: Does your work involve mostly sitting or standing, with walking for no more than 10 minutes at a time?
- GPAQ1P6: How long is your typical work day?
- GPAQ1P9: Does your [*recreation, sport or leisure time*] involve mostly sitting, reclining, or standing, with no physical activity lasting more than 10 minutes at a time?

GPAQ1P1

Follow the instructions in the table below to recode GPAQ1P1

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Rename the variable for the question " Does your work involve mostly sitting or standing, with walking for no more than 10 minutes at a time?" to GPAQ1P1</td></tr>
<tr><td>2</td><td>Create variables:
• P1orig
• P4orig</td></tr>
<tr><td>3</td><td>Make P1orig and P4orig equal to the original P1 and P4 in your dataset (P1orig=P1 , P4orig=P4)</td></tr>
<tr><td>4</td><td>Recode P1 and P4 with the following rule.

<table>
<tr><th>P1 Recode</th><th>P4 Recode</th></tr>
<tr><td>If GPAQ1P1=2 (no) then P1=2(no), otherwise P1 remains P1</td><td>If GPAQ1P1=2 (no) then P4=2(no), otherwise P4 remains P1</td></tr>
<tr><td>In Epi Info:

If GPAQ1P1=2 THEN
P1=2
ELSE
P1=P1
END</td><td>In Epi Info:

If GPAQ1P1=2 THEN
P4=2
ELSE
P4=P4
END</td></tr>
</table>
</td></tr>
</table>

Continued on next page

GPAQ1P6

The variable for the question " How long is your typical work day?", does not need to be coded into the dataset for the analysis of the GPAQ data.

Recode the variable to GPAQ1P6 and keep it in the original dataset.

GPAQ1P9

Follow the instructions in the table below to recode GPAQ1P9.

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Rename the variable for the question " Does your [recreation, sport or leisure time] involve mostly sitting, reclining, or standing, with no physical activity lasting more than 10 minutes at a time?" to GPAQ1P9</td></tr>
<tr><td>2</td><td>Create variables:
• P10orig
• P13orig</td></tr>
<tr><td>3</td><td>Make P10orig and P13orig equal to the original P10 and P13 in your dataset (P10orig=P10 , P13orig=P13)</td></tr>
<tr><td>4</td><td>Recode P10 and P13 with the following rule.
<table>
<tr><th>P10 Recode</th><th>P13 Recode</th></tr>
<tr><td>If GPAQ1P9=2 (no) then P10=2(no), otherwise P10 remains P10</td><td>If GPAQ1P9=2 (no) then P13=2(no), otherwise P13 remains P13</td></tr>
<tr><td>In Epi Info:

If GPAQ1P9=2 THEN
P10=2
ELSE
P10=P10
END</td><td>In Epi Info:

If GPAQ1P9=2 THEN
P13=2
ELSE
P13=P13
END</td></tr>
</table></td></tr>
</table>

Producing tables

Once you have completed the GPAQ 1 recode and saved the results to your dataset you will be able to produce all the results in the analysis section. Follow the instructions provided for each table to produce the results.

Analysis Guidelines and Calculations

Introduction

Analysis physical activity data can be very complicated and the result confusing. The following guidelines will help clarify the results of the physical activity and will also provide valuable information on the classifications. Make sure you use some of these guidelines when you report physical activity data.

- MET values are applied to vigorous and moderate intensity variables in the work and recreation settings. These have been calculated using an average of the typical types of activity undertaken. Different types of activities have been grouped together and given an MET value based on the intensity of the activity. Applying MET values to activity levels allows us to calculate total physical activity.

- The calculations below use multiple questions in the physical activity section. To simplify this a bit the questions have been clustered into four groups (as they appear in the Instrument). In the Instrument questions section of the table, only the group label appears. The specific questions for each groups is presented below.

  – Activity at work:
    - Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like [examples] for at least 10 minutes continuously?
    - In a typical week, on how many days do you do vigorous-intensity activities as part of your work?
    - How much time do you spend doing vigorous-intensity activities at work on a typical day?
    - Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking for at least 10 minutes continuously?
    - In a typical week, on how many days do you do moderate-intensity activities as part of your work?
    - How much time do you spend doing moderate-intensity activities at work on a typical day?

  – Travel to and from places:
    - Do you walk or use a bicycle for at least 10 minutes continuously to get to and from places?
    - In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?

Continued on next page

Analysis Guidelines and Calculations, Continued

Introduction (continued)

- How much time do you spend walking or bicycling for travel on a typical day?

– Recreational activities:

- Do you do any involve vigorous-intensity sports, fitness or recreational activities that cause large increases in breathing or heart rate like [examples] for at least 10 minutes continuously?
- In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational activities?
- How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?
- Do you do any involve moderate-intensity sports, fitness or recreational activities that cause large increases in breathing or heart rate like [examples] for at least 10 minutes continuously?
- In a typical week, on how many days do you do moderate--intensity sports, fitness or recreational activities?
- How much time do you spend doing moderate--intensity sports, fitness or recreational activities on a typical day?

– Sedentary behaviour :

- How much time do you usually spend sitting or reclining on a typical day?

MET values

For the calculation of physical activity the following MET values are used:

Domain	METS value
Work	• Moderate MET value = 4.0 • Vigorous MET value = 8.0
Transport	Cycling and walking MET value = 4.0
Recreation	• Moderate MET value = 4.0 • Vigorous MET value = 8.0

Levels of total physical activity

Description: percentage of participants classified into three categories of total physical activity

Instrument questions:

- activity at work
- travel to and from places
- recreational activities

Age Group	**Men** (N=)			**Women** (N=)			**Both Sexes** (N=)		
	Percent Low level of activity	Percent Moderate levels of activity	Percent High level of activity	Percent Low level of activity	Percent Moderate levels of activity	Percent High level of activity	Percent Low level of activity	Percent Moderate levels of activity	Percent High level of activity
	% 95% CI	% 95% CI	% 95% CI	% 95% CI	% 95% CI	% 95% CI	% 95% CI	% 95% CI	% 95% CI
25-34 years									
35-44 years									
45-54 years									
55-64 years									
25-64 years									

Analysis Information:

- Questions used (uses coding column as identifier):
  - Work: P1; P2; P3; P4; P5; P6
  - Transport: P7; P8; P9
  - Recreation: P10; P11; P12; P13; P14; P15
- Calculation: see table on next page

Continued on next page

Analysis Guidelines and Calculations, Continued

Levels of total physical activity (continued)

Total physical activity MET-minutes/week (= the sum of the total MET minutes of activity computed for each setting)

Equation: Total Physical Activity = [(P2 * P3 * 8) + (P5 * P6 * 4) + (P8 * P9 * 4) + (P11 * P12 * 8) + (P14 * P15* 4)]

Level of total physical activity	Physical activity cutoff value
High	• IF:(P2 + P11) >= 3 days AND Total physical activity MET minutes per week is >= 1500 **OR** • IF: (P2 + P5 + P8 + P11 + P14) >= 7 days AND total physical activity MET minutes per week is >= 3000
Moderate	• IF: (P2 + P11) >= 3 days AND ((P2 * P3) + (P11 * P12)) >= 60 minutes **OR** • IF: (P5 + P8 + P14) >= 5 days AND ((P5 * P6) + (P8 * P9) + (P14 * P15)>= 150 minutes **OR** • IF: (P2 + P5 + P8 + P11 + P14)>= 5 days AND Total physical activity MET minutes per week >= 600
Low	F: the value does not reach the criteria for either high or moderate levels of physical activity

Total physical activity

Description: median time of total physical activity per day.

Instrument questions

- activity at work
- travel to and from places
- recreational activities

Age Group	Men	Women	Both
	N=	N=	N=
	Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI
25-34 years			
35-44 years			
45-54 years			
55-64 years			
25-64 years			

Analysis Information:

- Questions used (uses coding column as identifier):
  - Work: P1; P2; P3; P4; P5; P6
  - Transport: P7; P8; P9
  - Recreation: P10; P11; P12; P13; P14; P15
- Calculation: Total physical activity MET-minutes/week
  - Total Physical Activity in minutes per week = [(P2 * P3] + (P5 * P6) + (P8 * P9) + (P11 * P12) + (P14 * (P15)]
  - (Total physical activity in minutes per week / 7) = Average total physical activity in minutes per day

Setting-specific physical activity

Description: median time spent per day in minutes, in work-, transport- and recreation-related physical activity

Instrument questions:

- activity at work
- travel to and from places
- recreational activities

Age Group	**Men** (N=)				**Women** (N=)				**Both Sexes** (N=)		
	Work	Transport	Recreation		Work	Transport	Recreation		Work	Transport	Recreation
	Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI		Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI		Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI	Median (inter-quartile range) 95% CI
25-34 years											
35-44 years											
45-54 years											
55-64 years											
25-64 years											

Analysis Information:

- Questions used (uses coding column as identifier):
  - Work: P1; P2; P3; P4; P5; P6
  - Transport: P7; P8; P9
  - Recreation: P10; P11; P12; P13; P14; P15
- Calculation: Setting specific physical activity- see table on next page

<table>
<tr><th>Setting</th><th>Recode</th><th>Equation</th></tr>
<tr><td>Work</td><td><table><tr><th>If…</th><th>Then…</th></tr><tr><td>P1=2 (No)</td><td>Recode P2 and P3 = 0</td></tr><tr><td>P4=2 (No)</td><td>Recode P5 and P6 = 0</td></tr></table></td><td>• Total work related physical activity in minutes per week= [(P2 * P3) + (P5 * P6)]
• Average total physical activity in minutes per day = (total work related physical activity in minutes per week/ 7)</td></tr>
<tr><td>Transport</td><td><table><tr><th>If…</th><th>Then…</th></tr><tr><td>P7=2 (No)</td><td>Recode P8 and P9 = 0</td></tr></table></td><td>• Total transport related physical activity in minutes per week = (P8 * P9)
• Average total transport activity in minutes per day = (total transport related physical activity in minutes per week/ 7)</td></tr>
<tr><td>Recreation</td><td><table><tr><th>If…</th><th>Then…</th></tr><tr><td>P10=2 (No)</td><td>Recode P11 and P12 = 0</td></tr><tr><td>P13=2 (No)</td><td>Recode P14 and P15 = 0</td></tr></table></td><td>• Total recreational related physical activity in minutes per week = [(P11 * P12) + (P14 * P15)]
• Average total recreational activity in minutes per day = (total recreational related physical activity in minutes per week/ 7)</td></tr>
</table>

Note: The recode is only used during the analysis of this table. Make sure you do not use the recoded values for other calculations.

No physical activity by setting

Description: percentage of participants classified as doing no work-transport- or recreational-related physical activity.

Instrument questions:

- activity at work
- travel to and from places
- recreational activities

Age Group	**Men** (N=)				**Women** (N=)				**Both Sexes** (N=)		
	Work	Transport	Recreation		Work	Transport	Recreation		Work	Transport	Recreation
	N=	N=	N=		N=	N=	N=		N=	N=	N=
	% 95% CI	% 95% CI	% 95% CI		% 95% CI	% 95% CI	% 95% CI		% 95% CI	% 95% CI	% 95% CI
25-34 years											
35-44 years											
45-54 years											
55-64 years											
25-64 years											

Analysis Information:

- Questions used (uses coding column as identifier):
  - Work: P1; P4
  - Transport: P7
  - Recreation: P10; P13
- Calculation: no physical activity by setting - see table below

Setting	Equation
Work	= (P1=2 and P4=2) / ((P1=1) + (P1=2) + (P4=1) + (P4=2))
Transport	= (P7=2) / ((P7=1) + (P7=2))

Recreation	= (P10=2 and P13=2) / ((P10=1) + (P10=2) + (P13=1) + (P13=2))

Sedentary Description: total time spent in sedentary activities per day.

Instrument question:

- sedentary behaviour

Age Group	**Men** (N=)			**Women** (N=)			**Both** (N=)	
	mean	median		mean	median		mean	median
	mean 95% CI	median (inter-quartile range) 95% CI		mean 95% CI	median (inter-quartile range) 95% CI		mean 95% CI	median (inter-quartile range) 95% CI
25-34 years 35-44 years 45-54 years 55-64 years								
25-64 years								

Analysis Information:

- Questions used (uses coding column as identifier): P16
- Calculation: Total sedentary activity per day = P16

Work related physical activity

Description: median time of work-related moderate- and vigorous-intensity physical activity per day.

Instrument questions:

- activity at work

Age Group	**Men** (N=)			**Women** (N=)			**Both** (N=)	
	Moderate	Vigorous		Moderate	Vigorous		Moderate	Vigorous
	median (inter-quartile range) 95% CI	median (inter-quartile range) 95% CI		median (inter-quartile range) 95% CI	median (inter-quartile range) 95% CI		median (inter-quartile range) 95% CI	median (inter-quartile range) 95% CI
25-34 years 35-44 years 45-54 years 55-64 years								
25-64 years								

Analysis Information:

- Questions used (uses coding column as identifier): P1; P2; P3; P4; P5; P6
- Calculation:

Setting	Recode	Equation
Moderate work related physical activity	**If…** / **Then…**: P4=2 (No) → Recode P5 and P6 = 0	Total moderate-intensity minutes per week= (P5 * P6)
Vigorous work related physical activity	**If…** / **Then…**: P1=2 (No) → Recode P2 and P3 = 0	Total vigorous-intensity minutes per week= (P2 * P3)

Recreational physical activity

Description: median time of recreational moderate- and vigorous-intensity physical activity.

Instrument question:

- recreational activities

Age Group	**Men** (N=)			**Women** (N=)			**Both** (N=)	
	Moderate	Vigorous		Moderate	Vigorous		Moderate	Vigorous
	median (inter-quartile range) 95% CI	median (inter-quartile range) 95% CI		median (inter-quartile range) 95% CI	median (inter-quartile range) 95% CI		median (inter-quartile range) 95% CI	median (inter-quartile range) 95% CI
25-34 years 35-44 years 45-54 years 55-64 years								
25-64 years								

Analysis Information:

- Questions used (uses coding column as identifier): P10; P11; P12; P13; P14; P15
- Calculation:

Setting	Recode	Equation
Moderate recreational related physical activity	**If…** / **Then…**: P13=2 (No) → Recode P14 and P15 = 0	Total moderate-intensity minutes per week= (P14 * P15)
Vigorous recreational related physical activity	**If…** / **Then..-**: P10=2 (No) → Recode P11 and P12 = 0	Total vigorous-intensity minutes per week= (P11 *P12)

Cleaning GPAQ With Epi Info

Introduction

GPAQ collects information on three domains. These domains are:
- Activity at work
- Travel to and from places
- Recreational activities.

For analysis purposes these domains can be further broken down into six different groups. These groups are:
- Work vigorous (codes P1-P3)
- Work moderate (codes P4-P6)
- Travel (codes P7-P9)
- Recreational vigorous (codes P10-P12)
- Recreational moderate (codes P13-P15)
- Sitting (code P16)

Note: You will need to use the questionnaire in order to understand the cleaning information.

Grouping the GPAQ sections

The GPAQ questionnaire can be cleaned for each domain independently. If a participant responded to questions P1-P3 and did not answer questions P4-P6, then they would qualify for inclusion for work vigorous (P1-P3) and they would not qualify for work moderate (P4-)6). This will result in a floating denominator during analysis.

Continued on next page

Cleaning GPAQ With Epi Info, Continued

Work vigorous P1-P3

- If P3a = 15, 30, 45, 60 and P3b is missing or empty then put the value from P3a into P3b. It is assumed that value was recorded in the hour column instead of the minute column.
- Create a new variable P3 and combine the hour and minute columns into one variable. P3 should be minutes. P3=[(P3a*60) + P3b]

Cleaning variable	CLN=1 (variable is clean/valid)	CLN=2 (variable is clean/valid)
P1CLN	P1=1 or P1=2	P1= missing
P2CLN	P1=1 AND P2=1-7	- P1=1 AND P2= missing - P1=2 AND P2=1-7
P3CLN	If P2CLN=1 AND (P3 >9 AND <1441)	If P2CLN=1 AND (P3>1440 or P3<10)

Work moderate P4-P6

- If P6a = 15, 30, 45, 60 and P6b is missing or empty then put the value from P6a into P6b. It is assumed that value was recorded in the hour column instead of the minute column.
- Create a new variable P6 and combine the hour and minute columns into one variable. P6 should be minutes. P6=[(P6a*60) + P6b]

Cleaning variable	CLN=1 (variable is clean/valid)	CLN=2 (variable is clean/valid)
P4CLN	P4=1 or P4=2	P4= missing
P5CLN	P4=1 and P5=1-7	- P4=1 and P5= missing - P4=2 and P5=1-7
P6CLN	If P5CLN=1 and (P6 >9 AND <1441)	If P5CLN=1 and (P6>1440 or P6<10)

Continued on next page

Cleaning GPAQ With Epi Info, Continued

Travel P7-P9

- If P9a = 15, 30, 45, 60 and P9b is missing or empty then put the value from P9a into P9b. It is assumed that value was recorded in the hour column instead of the minute column.
- Create a new variable P9 and combine the hour and minute columns into one variable. P9 should be minutes. P9=[(P9a*60) + P9b]

Cleaning variable	CLN=1 (variable is clean/valid)	CLN=2 (variable is clean/valid)
P7CLN	P7=1 or P7=2	P7= missing
P8CLN	P7=1 and P8=1-7	- P7=1 and P8= missing - P7=2 and P8=1-7
P9CLN	If P8CLN=1 and (P9 >9 AND <1441)	If P8CLN=1 and (P9>1440 or P9<10)

Recreational vigorous P10-P12

- If P12a = 15, 30, 45, 60 and P12b is missing or empty then put the value from P12a into P12b. It is assumed that value was recorded in the hour column instead of the minute column.
- Create a new variable P12 and combine the hour and minute columns into one variable. P12 should be minutes. P12=[(P12a*60) + P12b]

Cleaning variable	CLN=1 (variable is clean/valid)	CLN=2 (variable is clean/valid)
P10CLN	P10=1 or P10=2	P10= missing
P11CLN	P10=1 and P11=1-7	- P10=1 and P11= missing - P10=2 and P11=1-7
P12CLN	If P11CLN=1 and (P12 >9 AND <1441)	If P11CLN=1 and (P12>1440 or P12<10)

Continued on next page

Cleaning GPAQ With Epi Info, Continued

Recreational moderate P13-P15

- If P15a = 15, 30, 45, 60 and P15b is missing or empty then put the value from P15a into P15b. It is assumed that value was recorded in the hour column instead of the minute column.
- Create a new variable P15 and combine the hour and minute columns into one variable. P15 should be minutes. P15=[(P15a*60) + P15b]

Cleaning variable	CLN=1 (variable is clean/valid)	CLN=2 (variable is clean/valid)
P13CLN	P13=1 or P13=2	P13= missing
P14CLN	P13=1 and P14=1-7	- P13=1 and P14= missing - P13=2 and P14=1-7
P15CLN	If P14CLN=1 and (P15 >9 AND <1441)	If P14CLN=1 and (P15>1440 or P15<10)

Sitting P16

- If P16a = 15, 30, 45, 60 and P16b is missing or empty then put the value from P16a into P16b. It is assumed that value was recorded in the hour column instead of the minute column.
- Create a new variable P16 and combine the hour and minute columns into one variable. P16 should be minutes. P16=[(P16a*60) + P16b]

Cleaning variable	CLN=1 (variable is clean/valid)	CLN=2 (variable is clean/valid)
P16CLN	P16 <1441	P16>1440

Appendix IV – Informed Consent Forms

Informed consent

The association between cardiorespiratory fitness and performance in a submaximal stepping test standardised for energy expenditure

Dear Participant

Thank you for your interest in participating in the study (*The association between cardiorespiratory fitness and performance in a submaximal stepping test standardised for energy expenditure)* which is being conducted by the MRC/UCT Research Unit for Exercise Science and Sports Medicine. This phase is a continuation of the study and comprises a validation study which uses outcome measures from the step test (i.e. heart rate during the test and heart rate recovery after the test) to predict VO_2max measured during a treadmill protocol and a cross validation study which determines the relationship between VO_2max measured directly on a treadmill, and VO_2max predicted from the algorithm developed from the outcome measures of the step test and functional movement assessment.

Brief description of the study

In order to participate in the study you have to complete a pre-participation questionnaire that is designed to identify any factors which indicate a risk of you participating in exercise. This should take a few minutes and is designed to identify any factors that indicate a risk of you participating in exercise. If you satisfy the requirements of this test and fulfil the inclusion criteria for participation, you will be recruited into the study. You will then answer questions from a questionnaire designed to predict your physical activity level.

On the first day of testing we will measure your height, body mass and the thickness of 7 skinfolds. The skinfold measurement is not painful and will involve the researcher gently pinching the skin and underlying fat. You will then perform a step test and a functional participation screen in random order. For the step test a strap with a small heart rate transmitter will be attached around your chest and a monitor, the size of a watch will be attached to your wrist. The metronome will be set at 24 steps per minute. You will be informed of the duration of the test which depends on your weight and step height. This will range between 5 and 15 minutes. The researcher will demonstrate stepping and you have 10 seconds to practise stepping to the metronome rhythm. During the test heart rate will be measured continuously. The researcher will continually inform you about how much time

you have to complete the test. The researcher informs you when you are half way in the test so you can change the leading leg when stepping. At the end of the test you will stand motionless for 2 minutes while heart rate is recorded. You then remove the heart rate monitor.

On the same day as the step test in random order you will perform the functional participation screen. You warm up by doing dynamic stretching followed by 5 minutes of submaximal cycling on a stationary ergometer. You then do 7 screen tests namely; overhead squat, single leg hurdle, split squat, shoulder mobility, active leg raise, stability push up and seated rotation designed to test movement pattern. The movements will be explained and demonstrated by the researcher. The testing protocol takes about 12 minutes. All tests are scored out of three, with the possibility of scoring from 0 – 3 depending on how accurate your performance is and whether or not you feel pain.

You will come back to the laboratory after 2-5 days to do the VO_2max test on a treadmill. The test protocol will be explained and you warm up for 6 minutes. The researcher will put a mask over your mouth and nose for the measurement of oxygen consumption. This does not restrict your breathing at all. The oxygen analyser will be switched on and the test begins at a treadmill speed of 2.74 km/ h and 10% gradient. Speed and incline are increased every 3 minutes until you cannot continue with the test. You will be verbally encouraged throughout the test to produce a maximum effort performance. After the test a researcher will assist you in removing the mask.

Possible risks of participation

The step test used in this study poses very low risk to the participants, similar to the risks associated with stepping when walking or jogging at a moderate intensity for 12 minutes. All the Functional participation screen test movements are slow and controlled, posing no risk to participants. The VO_2max test on the treadmill is a maximum test which is exhaustive. When you feel you cannot continue running you should stop. Should there be any unexpected event such a tripping or straining a muscle while participating in this trial, on-site medical care will be provided by one of the medical personnel in the building who are always on call via an emergency system that is in place.

Benefits

There is no financial remuneration for participation in this study. However, after the results have been analysed we will inform you of the significance of our findings. We will also provide you with a comprehensive assessment of your performance tests. You will also receive an invitation to our annual research evening for research participants which will be held in November.

Ethics and insurance

The study will be performed in accordance with the principles of the Declaration of Helsinki, ICH Good Clinical Practice and the laws of South Africa.

Please note that UCT does offer a no-fault insurance that will cover all participants in the event that something may go wrong. This insurance will provide prompt payment of compensation for any trial-related injury according to the Association of the British Pharmaceutical Industry (ABPI) guidelines (1991). These guidelines recommend that UCT, without any legal commitment, should compensate you without you having to prove that UCT is at fault. An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study investigators immediately of any injuries during the trial, whether they are research-related or other related complications. UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected.

Statement of understanding and consent:

I confirm that the exact procedure and techniques, and possible complications of the above tests have been thoroughly explained to me. I am free to withdraw from the study at any time, should I choose to do so. I understand that I may ask questions at any time during the testing procedure. I know that the personal information required by the researchers and derived from the testing procedure will remain strictly confidential and will only be revealed as a number in statistical analysis.

I have carefully read this form and understand the nature, purpose and procedures of this study. I agree to participate in this research project of the MRC / UCT Research Unit for Exercise Science and Sports Medicine.

Name of volunteer: ……..

Signature:……..……

Name of investigator: ……..……

Signature: ……..……..

Date: **……..**

==========

Contact details

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Appendix V – Subject Information Sheets

Subject information sheet

The association between cardiorespiratory fitness and performance in a submaximal stepping test standardised for energy expenditure

Dear Participant

Thank you for your interest in participating in the study (*The association between cardiorespiratory fitness and performance in a submaximal stepping test standardised for energy expenditure*) which is being conducted by the MRC/UCT Research Unit for Exercise Science and sports Medicine. This phase is a continuation of the study and comprises a validation study which uses outcome measures from the step test (i.e. heart rate during the test and heart rate recovery after the test) to predict VO_2max measured during a treadmill protocol and a cross validation study which determines the relationship between VO_2max measured directly on a treadmill, and VO_2max predicted from the algorithm developed from the outcome measures of the step test and functional movement assessment.

Brief description of the study

For you to participate in the study you have to complete the pre-participation questionnaire that is designed to identify any factors which indicate a risk of you doing exercise. This takes a few minutes. You may be asked to get cleared by your medical doctor if you have any risk factors. If you satisfy the requirements of this test and fulfil the inclusion criteria for participation, you will be recruited into the study. The study will be explained to you and you ask questions after which you sign the informed consent form. You will answer questions from a questionnaire designed to predict your physical activity level.

On the first day of testing we will measure the thickness of 7 skinfolds on your torso, arms and legs. This is not painful and will involve the researcher gently pinching the skin and underlying fat to record the measurement. We also measure and record you height and body mass. You are required to maintain a constant diet and physical activity programme during the testing days.

Step test

On the first day of testing you do a step test at 24 steps per minute that elicits 45 000 J. The researcher demonstrates stepping and you are allowed time to practise after which testing begins. Test duration is determined by your body mass and step height. Heart rate is measured during the test and 2 minutes after the test.

The Functional Participation Screen

On the same day as the step test in random order you will perform a functional participation screen to determine whether you have movement dysfunction, which increases the risk of injury due to compensatory movements associated with poor mobility and stability. You first warm up by stretching and cycling on a stationary ergometer for 5 minutes. Then you perform 7 screen tests namely: overhead squat, single leg hurdle, split squat, shoulder mobility, active leg raise, stability push up and seated rotation designed to test movement pattern. The movements will be explained and demonstrated. The testing protocol takes about 12 minutes. All tests are scored out of three, with the possibility of scoring from 0 – 3.

VO_2max test

On your next visit, after 2-5 days, you will perform a VO_2max test on a treadmill. You warm up for 6 minutes. The test begins at a treadmill speed of 2.74 km/ h and 10% gradient. Speed and incline are increased every 3 minutes until you cannot continue with the test. You will be verbally encouraged throughout the test to produce a maximum effort performance. During the test oxygen consumption and respiratory exchange ratio are measured using an Oxycon. VO_2max will be defined as the highest oxygen consumption measured for 30 s during the test.

Possible risks of taking part

The step test used in this study poses very low risk to the participants, similar to the risks associated with stepping when walking or jogging at a moderate intensity for 12 minutes. All the Functional participation screen test movements are slow and controlled, posing no risk to participants. The VO_2max test on the treadmill is a maximum test which is exhaustive. When you feel you cannot continue running you should stop.

Benefits

At the end of the study we will provide you with a report of your data (VO_2max, RER, heart rate and body composition). After the results have been analysed we will inform you of the significance of our findings.

Ethics and insurance

The study will be performed in accordance with the principles of the Declaration of Helsinki, ICH Good Clinical Practice and the laws of South Africa.

Please note that UCT does offer a no-fault insurance that will cover all participants in the event that something may go wrong. This insurance will provide prompt payment of compensation for any trial-related injury according to the Association of the British Pharmaceutical Industry (ABPI) guidelines (1991). These guidelines recommend that UCT, without any legal commitment, should compensate you without you having to prove that UCT is at fault. An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study investigators immediately of any injuries during the trial, whether they are research-related or other related complications. UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected.

Appendix VI – SPSS Data Output

```
 CROSSTABS
  /TABLES=Sex Age_group Physical_activity_levelBY OverHead_Squat SL_Hurdle Sp
lit_Squat
    Shoulder_MobilityAsymetric_LegRaiseStability_PushUpSeated_Rotation
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ PHI
  /CELLS=COUNT EXPECTED ROW COLUMN TOTAL PROP
  /COUNT ROUND CELL.


 CROSSTABS
  /TABLES=Sex Age_group Physical_activity_levelBY OverHead_Squat SL_Hurdle Sp
lit_Squat
    Shoulder_MobilityAsymetric_LegRaiseStability_PushUpSeated_Rotation
  /FORMAT=AVALUE TABLES
  /STATISTICS=CHISQ
  /CELLS=COUNT EXPECTED ROW COLUMN TOTAL PROP
  /COUNT ROUND CELL.
```

Crosstabs

Notes

Output Created		16-APR-2018 12:36:48
Comments		
Input	Data	C:\Users\Adri\Documents\clean data.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	262
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each table are based on all the cases with valid data in the specified range(s) for all variables in each table.
Syntax		CROSSTABS /TABLES=Sex Age_group Physical_activity_level BY OverHead_Squat SL_Hurdle Split_Squat Shoulder_Mobility Asymetric_LegRaise Stability_PushUp Seated_Rotation /FORMAT=AVALUE TABLES /STATISTICS=CHISQ /CELLS=COUNT EXPECTED ROW COLUMN TOTAL PROP /COUNT ROUND CELL.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.03
	Dimensions Requested	2
	Cells Available	524245

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Sex * Over Head Squat	262	100.0%	0	0.0%	262	100.0%
Sex * SL Hurdle	262	100.0%	0	0.0%	262	100.0%
Sex * Split Squat	262	100.0%	0	0.0%	262	100.0%
Sex * Shoulder Mobility	262	100.0%	0	0.0%	262	100.0%
Sex * Asymetric Leg Raise	262	100.0%	0	0.0%	262	100.0%
Sex * Stability Push Up	262	100.0%	0	0.0%	262	100.0%
Sex * Seated Rotation	262	100.0%	0	0.0%	262	100.0%
Age group * Over Head Squat	262	100.0%	0	0.0%	262	100.0%
Age group * SL Hurdle	262	100.0%	0	0.0%	262	100.0%
Age group * Split Squat	262	100.0%	0	0.0%	262	100.0%
Age group * Shoulder Mobility	262	100.0%	0	0.0%	262	100.0%
Age group * Asymetric Leg Raise	262	100.0%	0	0.0%	262	100.0%
Age group * Stability Push Up	262	100.0%	0	0.0%	262	100.0%
Age group * Seated Rotation	262	100.0%	0	0.0%	262	100.0%
Physical_activity_level * Over Head Squat	262	100.0%	0	0.0%	262	100.0%
Physical_activity_level * SL Hurdle	262	100.0%	0	0.0%	262	100.0%
Physical_activity_level * Split Squat	262	100.0%	0	0.0%	262	100.0%
Physical_activity_level * Shoulder Mobility	262	100.0%	0	0.0%	262	100.0%
Physical_activity_level * Asymetric Leg Raise	262	100.0%	0	0.0%	262	100.0%
Physical_activity_level * Stability Push Up	262	100.0%	0	0.0%	262	100.0%
Physical_activity_level * Seated Rotation	262	100.0%	0	0.0%	262	100.0%

Sex * Over Head Squat

Crosstab

			Over Head Squat			
			1	2	3	Total
Sex	Male	Count	12a	81a	42a	135
		Expected Count	14.4	82.4	38.1	135.0
		% within Sex	8.9%	60.0%	31.1%	100.0%
		% within Over Head Squat	42.9%	50.6%	56.8%	51.5%
		% of Total	4.6%	30.9%	16.0%	51.5%
	Female	Count	16a	79a	32a	127
		Expected Count	13.6	77.6	35.9	127.0
		% within Sex	12.6%	62.2%	25.2%	100.0%
		% within Over Head Squat	57.1%	49.4%	43.2%	48.5%
		% of Total	6.1%	30.2%	12.2%	48.5%
Total		Count	28	160	74	262
		Expected Count	28.0	160.0	74.0	262.0
		% within Sex	10.7%	61.1%	28.2%	100.0%
		% within Over Head Squat	100.0%	100.0%	100.0%	100.0%
		% of Total	10.7%	61.1%	28.2%	100.0%

Each subscript letter denotes a subset of Over Head Squat categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.705[a]	2	.426
Likelihood Ratio	1.710	2	.425
Linear-by-Linear Association	1.684	1	.194
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.57.

Sex * SL Hurdle

Crosstab

			SL Hurdle			
			1	2	3	Total
Sex	Male	Count	15[a, b]	79[b]	41[a]	135
		Expected Count	17.0	85.5	32.5	135.0
		% within Sex	11.1%	58.5%	30.4%	100.0%
		% within SL Hurdle	45.5%	47.6%	65.1%	51.5%
		% of Total	5.7%	30.2%	15.6%	51.5%
	Female	Count	18[a, b]	87[b]	22[a]	127
		Expected Count	16.0	80.5	30.5	127.0
		% within Sex	14.2%	68.5%	17.3%	100.0%
		% within SL Hurdle	54.5%	52.4%	34.9%	48.5%
		% of Total	6.9%	33.2%	8.4%	48.5%
Total		Count	33	166	63	262
		Expected Count	33.0	166.0	63.0	262.0
		% within Sex	12.6%	63.4%	24.0%	100.0%
		% within SL Hurdle	100.0%	100.0%	100.0%	100.0%
		% of Total	12.6%	63.4%	24.0%	100.0%

Each subscript letter denotes a subset of SL Hurdle categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.150[a]	2	.046
Likelihood Ratio	6.235	2	.044
Linear-by-Linear Association	4.789	1	.029
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 16.00.

Sex * Split Squat

Crosstab

			Split Squat			
			1	2	3	Total
Sex	Male	Count	14a	51a	70a	135
		Expected Count	11.9	50.5	72.7	135.0
		% within Sex	10.4%	37.8%	51.9%	100.0%
		% within Split Squat	60.9%	52.0%	49.6%	51.5%
		% of Total	5.3%	19.5%	26.7%	51.5%
	Female	Count	9a	47a	71a	127
		Expected Count	11.1	47.5	68.3	127.0
		% within Sex	7.1%	37.0%	55.9%	100.0%
		% within Split Squat	39.1%	48.0%	50.4%	48.5%
		% of Total	3.4%	17.9%	27.1%	48.5%
Total		Count	23	98	141	262
		Expected Count	23.0	98.0	141.0	262.0
		% within Sex	8.8%	37.4%	53.8%	100.0%
		% within Split Squat	100.0%	100.0%	100.0%	100.0%
		% of Total	8.8%	37.4%	53.8%	100.0%

Each subscript letter denotes a subset of Split Squat categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.014[a]	2	.602
Likelihood Ratio	1.022	2	.600
Linear-by-Linear Association	.829	1	.362
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.15.

Sex * Shoulder Mobility

Crosstab

			Shoulder Mobility			
			1	2	3	Total
Sex	Male	Count	20a	53b	62b	135
		Expected Count	12.9	49.5	72.7	135.0
		% within Sex	14.8%	39.3%	45.9%	100.0%
		% within Shoulder Mobility	80.0%	55.2%	44.0%	51.5%
		% of Total	7.6%	20.2%	23.7%	51.5%
	Female	Count	5a	43b	79b	127
		Expected Count	12.1	46.5	68.3	127.0
		% within Sex	3.9%	33.9%	62.2%	100.0%
		% within Shoulder Mobility	20.0%	44.8%	56.0%	48.5%
		% of Total	1.9%	16.4%	30.2%	48.5%
Total		Count	25	96	141	262
		Expected Count	25.0	96.0	141.0	262.0
		% within Sex	9.5%	36.6%	53.8%	100.0%
		% within Shoulder Mobility	100.0%	100.0%	100.0%	100.0%
		% of Total	9.5%	36.6%	53.8%	100.0%

Each subscript letter denotes a subset of Shoulder Mobility categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	11.858[a]	2	.003
Likelihood Ratio	12.491	2	.002
Linear-by-Linear Association	10.987	1	.001
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.12.

Sex * Asymetric Leg Raise

Crosstab

			Asymetric Leg Raise			
			1	2	3	Total
Sex	Male	Count	25a	68b	42c	135
		Expected Count	14.4	59.3	61.3	135.0
		% within Sex	18.5%	50.4%	31.1%	100.0%
		% within Asymetric Leg Raise	89.3%	59.1%	35.3%	51.5%
		% of Total	9.5%	26.0%	16.0%	51.5%
	Female	Count	3a	47b	77c	127
		Expected Count	13.6	55.7	57.7	127.0
		% within Sex	2.4%	37.0%	60.6%	100.0%
		% within Asymetric Leg Raise	10.7%	40.9%	64.7%	48.5%
		% of Total	1.1%	17.9%	29.4%	48.5%
Total		Count	28	115	119	262
		Expected Count	28.0	115.0	119.0	262.0
		% within Sex	10.7%	43.9%	45.4%	100.0%
		% within Asymetric Leg Raise	100.0%	100.0%	100.0%	100.0%
		% of Total	10.7%	43.9%	45.4%	100.0%

Each subscript letter denotes a subset of Asymetric Leg Raise categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	31.199[a]	2	.000
Likelihood Ratio	33.808	2	.000
Linear-by-Linear Association	30.879	1	.000
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.57.

Sex * Stability Push Up

Crosstab

			Stability Push Up			
			1	2	3	Total
Sex	Male	Count	1[a]	19[b]	115[c]	135
		Expected Count	15.5	36.6	83.0	135.0
		% within Sex	0.7%	14.1%	85.2%	100.0%
		% within Stability Push Up	3.3%	26.8%	71.4%	51.5%
		% of Total	0.4%	7.3%	43.9%	51.5%
	Female	Count	29[a]	52[b]	46[c]	127
		Expected Count	14.5	34.4	78.0	127.0
		% within Sex	22.8%	40.9%	36.2%	100.0%
		% within Stability Push Up	96.7%	73.2%	28.6%	48.5%
		% of Total	11.1%	19.8%	17.6%	48.5%
Total		Count	30	71	161	262
		Expected Count	30.0	71.0	161.0	262.0
		% within Sex	11.5%	27.1%	61.5%	100.0%
		% within Stability Push Up	100.0%	100.0%	100.0%	100.0%
		% of Total	11.5%	27.1%	61.5%	100.0%

Each subscript letter denotes a subset of Stability Push Up categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	70.865[a]	2	.000
Likelihood Ratio	79.071	2	.000
Linear-by-Linear Association	68.717	1	.000
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 14.54.

Sex * Seated Rotation

Crosstab

			Seated Rotation			
			1	2	3	Total
Sex	Male	Count	33a	86b	16b	135
		Expected Count	25.2	87.6	22.2	135.0
		% within Sex	24.4%	63.7%	11.9%	100.0%
		% within Seated Rotation	67.3%	50.6%	37.2%	51.5%
		% of Total	12.6%	32.8%	6.1%	51.5%
	Female	Count	16a	84b	27b	127
		Expected Count	23.8	82.4	20.8	127.0
		% within Sex	12.6%	66.1%	21.3%	100.0%
		% within Seated Rotation	32.7%	49.4%	62.8%	48.5%
		% of Total	6.1%	32.1%	10.3%	48.5%
Total		Count	49	170	43	262
		Expected Count	49.0	170.0	43.0	262.0
		% within Sex	18.7%	64.9%	16.4%	100.0%
		% within Seated Rotation	100.0%	100.0%	100.0%	100.0%
		% of Total	18.7%	64.9%	16.4%	100.0%

Each subscript letter denotes a subset of Seated Rotation categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.499[a]	2	.014
Likelihood Ratio	8.647	2	.013
Linear-by-Linear Association	8.399	1	.004
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 20.84.

Age group * Over Head Squat

Crosstab

			Over Head Squat			
			1	2	3	Total
Age group	20-30	Count	9[a]	44[a]	29[a]	82
		Expected Count	8.8	50.1	23.2	82.0
		% within Age group	11.0%	53.7%	35.4%	100.0%
		% within Over Head Squat	32.1%	27.5%	39.2%	31.3%
		% of Total	3.4%	16.8%	11.1%	31.3%
	31-40	Count	6[a]	35[a]	17[a]	58
		Expected Count	6.2	35.4	16.4	58.0
		% within Age group	10.3%	60.3%	29.3%	100.0%
		% within Over Head Squat	21.4%	21.9%	23.0%	22.1%
		% of Total	2.3%	13.4%	6.5%	22.1%
	41-50	Count	6[a]	32[a]	21[a]	59
		Expected Count	6.3	36.0	16.7	59.0
		% within Age group	10.2%	54.2%	35.6%	100.0%
		% within Over Head Squat	21.4%	20.0%	28.4%	22.5%
		% of Total	2.3%	12.2%	8.0%	22.5%
	51-60	Count	7[a]	49[a]	7[b]	63
		Expected Count	6.7	38.5	17.8	63.0
		% within Age group	11.1%	77.8%	11.1%	100.0%
		% within Over Head Squat	25.0%	30.6%	9.5%	24.0%
		% of Total	2.7%	18.7%	2.7%	24.0%
Total		Count	28	160	74	262
		Expected Count	28.0	160.0	74.0	262.0
		% within Age group	10.7%	61.1%	28.2%	100.0%
		% within Over Head Squat	100.0%	100.0%	100.0%	100.0%
		% of Total	10.7%	61.1%	28.2%	100.0%

Each subscript letter denotes a subset of Over Head Squat categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.283[a]	6	.039
Likelihood Ratio	14.883	6	.021
Linear-by-Linear Association	4.201	1	.040
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.20.

Age group * SL Hurdle

Crosstab

			SL Hurdle			
			1	2	3	Total
Age group	20-30	Count	4a	45a	33b	82
		Expected Count	10.3	52.0	19.7	82.0
		% within Age group	4.9%	54.9%	40.2%	100.0%
		% within SL Hurdle	12.1%	27.1%	52.4%	31.3%
		% of Total	1.5%	17.2%	12.6%	31.3%
	31-40	Count	5a	39a	14a	58
		Expected Count	7.3	36.7	13.9	58.0
		% within Age group	8.6%	67.2%	24.1%	100.0%
		% within SL Hurdle	15.2%	23.5%	22.2%	22.1%
		% of Total	1.9%	14.9%	5.3%	22.1%
	41-50	Count	7a	41a	11a	59
		Expected Count	7.4	37.4	14.2	59.0
		% within Age group	11.9%	69.5%	18.6%	100.0%
		% within SL Hurdle	21.2%	24.7%	17.5%	22.5%
		% of Total	2.7%	15.6%	4.2%	22.5%
	51-60	Count	17a	41b	5c	63
		Expected Count	7.9	39.9	15.1	63.0

Crosstab

		SL Hurdle			
		1	2	3	Total
	% within Age group	27.0%	65.1%	7.9%	100.0%
	% within SL Hurdle	51.5%	24.7%	7.9%	24.0%
	% of Total	6.5%	15.6%	1.9%	24.0%
Total	Count	33	166	63	262
	Expected Count	33.0	166.0	63.0	262.0
	% within Age group	12.6%	63.4%	24.0%	100.0%
	% within SL Hurdle	100.0%	100.0%	100.0%	100.0%
	% of Total	12.6%	63.4%	24.0%	100.0%

Each subscript letter denotes a subset of SL Hurdle categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	32.897[a]	6	.000
Likelihood Ratio	32.582	6	.000
Linear-by-Linear Association	29.563	1	.000
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.31.

Age group * Split Squat

Crosstab

			Split Squat			
			1	2	3	Total
Age group	20-30	Count	2[a]	21[a]	59[b]	82
		Expected Count	7.2	30.7	44.1	82.0
		% within Age group	2.4%	25.6%	72.0%	100.0%
		% within Split Squat	8.7%	21.4%	41.8%	31.3%
		% of Total	0.8%	8.0%	22.5%	31.3%
	31-40	Count	1[a]	21[a, b]	36[b]	58
		Expected Count	5.1	21.7	31.2	58.0
		% within Age group	1.7%	36.2%	62.1%	100.0%
		% within Split Squat	4.3%	21.4%	25.5%	22.1%
		% of Total	0.4%	8.0%	13.7%	22.1%
	41-50	Count	3[a]	27[a]	29[a]	59
		Expected Count	5.2	22.1	31.8	59.0
		% within Age group	5.1%	45.8%	49.2%	100.0%
		% within Split Squat	13.0%	27.6%	20.6%	22.5%
		% of Total	1.1%	10.3%	11.1%	22.5%
	51-60	Count	17[a]	29[b]	17[c]	63
		Expected Count	5.5	23.6	33.9	63.0
		% within Age group	27.0%	46.0%	27.0%	100.0%
		% within Split Squat	73.9%	29.6%	12.1%	24.0%
		% of Total	6.5%	11.1%	6.5%	24.0%
Total		Count	23	98	141	262
		Expected Count	23.0	98.0	141.0	262.0
		% within Age group	8.8%	37.4%	53.8%	100.0%
		% within Split Squat	100.0%	100.0%	100.0%	100.0%
		% of Total	8.8%	37.4%	53.8%	100.0%

Each subscript letter denotes a subset of Split Squat categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	51.584[a]	6	.000
Likelihood Ratio	47.985	6	.000
Linear-by-Linear Association	40.002	1	.000
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.09.

Age group * Shoulder Mobility

Crosstab

			Shoulder Mobility			
			1	2	3	Total
Age group	20-30	Count	4a	24a	54b	82
		Expected Count	7.8	30.0	44.1	82.0
		% within Age group	4.9%	29.3%	65.9%	100.0%
		% within Shoulder Mobility	16.0%	25.0%	38.3%	31.3%
		% of Total	1.5%	9.2%	20.6%	31.3%
	31-40	Count	5a	24a	29a	58
		Expected Count	5.5	21.3	31.2	58.0
		% within Age group	8.6%	41.4%	50.0%	100.0%
		% within Shoulder Mobility	20.0%	25.0%	20.6%	22.1%
		% of Total	1.9%	9.2%	11.1%	22.1%
	41-50	Count	8a	23a	28a	59
		Expected Count	5.6	21.6	31.8	59.0
		% within Age group	13.6%	39.0%	47.5%	100.0%
		% within Shoulder Mobility	32.0%	24.0%	19.9%	22.5%
		% of Total	3.1%	8.8%	10.7%	22.5%
	51-60	Count	8a	25a	30a	63
		Expected Count	6.0	23.1	33.9	63.0
		% within Age group	12.7%	39.7%	47.6%	100.0%

Crosstab

		Shoulder Mobility			
		1	2	3	Total
	% within Shoulder Mobility	32.0%	26.0%	21.3%	24.0%
	% of Total	3.1%	9.5%	11.5%	24.0%
Total	Count	25	96	141	262
	Expected Count	25.0	96.0	141.0	262.0
	% within Age group	9.5%	36.6%	53.8%	100.0%
	% within Shoulder Mobility	100.0%	100.0%	100.0%	100.0%
	% of Total	9.5%	36.6%	53.8%	100.0%

Each subscript letter denotes a subset of Shoulder Mobility categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.653[a]	6	.194
Likelihood Ratio	8.851	6	.182
Linear-by-Linear Association	6.450	1	.011
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.53.

Age group * Asymetric Leg Raise

Crosstab

			Asymetric Leg Raise			
			1	2	3	Total
Age group	20-30	Count	8[a]	43[a]	31[a]	82
		Expected Count	8.8	36.0	37.2	82.0
		% within Age group	9.8%	52.4%	37.8%	100.0%
		% within Asymetric Leg Raise	28.6%	37.4%	26.1%	31.3%
		% of Total	3.1%	16.4%	11.8%	31.3%
	31-40	Count	6[a]	27[a]	25[a]	58
		Expected Count	6.2	25.5	26.3	58.0
		% within Age group	10.3%	46.6%	43.1%	100.0%
		% within Asymetric Leg Raise	21.4%	23.5%	21.0%	22.1%
		% of Total	2.3%	10.3%	9.5%	22.1%
	41-50	Count	10[a]	20[b]	29[a, b]	59
		Expected Count	6.3	25.9	26.8	59.0
		% within Age group	16.9%	33.9%	49.2%	100.0%
		% within Asymetric Leg Raise	35.7%	17.4%	24.4%	22.5%
		% of Total	3.8%	7.6%	11.1%	22.5%
	51-60	Count	4[a]	25[a]	34[a]	63
		Expected Count	6.7	27.7	28.6	63.0
		% within Age group	6.3%	39.7%	54.0%	100.0%
		% within Asymetric Leg Raise	14.3%	21.7%	28.6%	24.0%
		% of Total	1.5%	9.5%	13.0%	24.0%
Total		Count	28	115	119	262
		Expected Count	28.0	115.0	119.0	262.0
		% within Age group	10.7%	43.9%	45.4%	100.0%
		% within Asymetric Leg Raise	100.0%	100.0%	100.0%	100.0%
		% of Total	10.7%	43.9%	45.4%	100.0%

Each subscript letter denotes a subset of Asymetric Leg Raise categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.712[a]	6	.190
Likelihood Ratio	8.618	6	.196
Linear-by-Linear Association	2.625	1	.105
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.20.

Age group * Stability Push Up

Crosstab

			Stability Push Up			
			1	2	3	Total
Age group	20-30	Count	7a	19a	56a	82
		Expected Count	9.4	22.2	50.4	82.0
		% within Age group	8.5%	23.2%	68.3%	100.0%
		% within Stability Push Up	23.3%	26.8%	34.8%	31.3%
		% of Total	2.7%	7.3%	21.4%	31.3%
	31-40	Count	8a	12a	38a	58
		Expected Count	6.6	15.7	35.6	58.0
		% within Age group	13.8%	20.7%	65.5%	100.0%
		% within Stability Push Up	26.7%	16.9%	23.6%	22.1%
		% of Total	3.1%	4.6%	14.5%	22.1%
	41-50	Count	4a	17a	38a	59
		Expected Count	6.8	16.0	36.3	59.0
		% within Age group	6.8%	28.8%	64.4%	100.0%
		% within Stability Push Up	13.3%	23.9%	23.6%	22.5%
		% of Total	1.5%	6.5%	14.5%	22.5%
	51-60	Count	11a	23a	29b	63
		Expected Count	7.2	17.1	38.7	63.0
		% within Age group	17.5%	36.5%	46.0%	100.0%

Crosstab

		Stability Push Up			
		1	2	3	Total
	% within Stability Push Up	36.7%	32.4%	18.0%	24.0%
	% of Total	4.2%	8.8%	11.1%	24.0%
Total	Count	30	71	161	262
	Expected Count	30.0	71.0	161.0	262.0
	% within Age group	11.5%	27.1%	61.5%	100.0%
	% within Stability Push Up	100.0%	100.0%	100.0%	100.0%
	% of Total	11.5%	27.1%	61.5%	100.0%

Each subscript letter denotes a subset of Stability Push Up categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.768[a]	6	.096
Likelihood Ratio	10.832	6	.094
Linear-by-Linear Association	5.488	1	.019
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.64.

Age group * Seated Rotation

Crosstab

			Seated Rotation			
			1	2	3	Total
Age group	20-30	Count	14a	53a	15a	82
		Expected Count	15.3	53.2	13.5	82.0
		% within Age group	17.1%	64.6%	18.3%	100.0%
		% within Seated Rotation	28.6%	31.2%	34.9%	31.3%
		% of Total	5.3%	20.2%	5.7%	31.3%
	31-40	Count	7a	41a	10a	58
		Expected Count	10.8	37.6	9.5	58.0
		% within Age group	12.1%	70.7%	17.2%	100.0%
		% within Seated Rotation	14.3%	24.1%	23.3%	22.1%
		% of Total	2.7%	15.6%	3.8%	22.1%
	41-50	Count	14a	33a	12a	59
		Expected Count	11.0	38.3	9.7	59.0
		% within Age group	23.7%	55.9%	20.3%	100.0%
		% within Seated Rotation	28.6%	19.4%	27.9%	22.5%
		% of Total	5.3%	12.6%	4.6%	22.5%
	51-60	Count	14a	43a	6a	63
		Expected Count	11.8	40.9	10.3	63.0
		% within Age group	22.2%	68.3%	9.5%	100.0%
		% within Seated Rotation	28.6%	25.3%	14.0%	24.0%
		% of Total	5.3%	16.4%	2.3%	24.0%
Total		Count	49	170	43	262
		Expected Count	49.0	170.0	43.0	262.0
		% within Age group	18.7%	64.9%	16.4%	100.0%
		% within Seated Rotation	100.0%	100.0%	100.0%	100.0%
		% of Total	18.7%	64.9%	16.4%	100.0%

Each subscript letter denotes a subset of Seated Rotation categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.413[a]	6	.379
Likelihood Ratio	6.834	6	.336
Linear-by-Linear Association	2.232	1	.135
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 9.52.

Physical_activity_level * Over Head Squat

Crosstab

			Over Head Squat		
			1	2	3
Physical_activity_level	Above	Count	10a	61a	32a
		Expected Count	11.0	62.9	29.1
		% within Physical_activity_level	9.7%	59.2%	31.1%
		% within Over Head Squat	35.7%	38.1%	43.2%
		% of Total	3.8%	23.3%	12.2%
	Achieved	Count	6a	50a	26a
		Expected Count	8.8	50.1	23.2
		% within Physical_activity_level	7.3%	61.0%	31.7%
		% within Over Head Squat	21.4%	31.3%	35.1%
		% of Total	2.3%	19.1%	9.9%
	Below	Count	12a	49a, b	16b
		Expected Count	8.2	47.0	21.7

Crosstab

			Total
Physical_activity_level	Above	Count	103
		Expected Count	103.0
		% within Physical_activity_level	100.0%
		% within Over Head Squat	39.3%
		% of Total	39.3%
	Achieved	Count	82
		Expected Count	82.0
		% within Physical_activity_level	100.0%
		% within Over Head Squat	31.3%
		% of Total	31.3%
	Below	Count	77
		Expected Count	77.0

Crosstab

		Over Head Squat		
		1	2	3
	% within Physical_activity_level	15.6%	63.6%	20.8%
	% within Over Head Squat	42.9%	30.6%	21.6%
	% of Total	4.6%	18.7%	6.1%
Total	Count	28	160	74
	Expected Count	28.0	160.0	74.0
	% within Physical_activity_level	10.7%	61.1%	28.2%
	% within Over Head Squat	100.0%	100.0%	100.0%
	% of Total	10.7%	61.1%	28.2%

Crosstab

		Total
	% within Physical_activity_level	100.0%
	% within Over Head Squat	29.4%
	% of Total	29.4%
Total	Count	262
	Expected Count	262.0
	% within Physical_activity_level	100.0%
	% within Over Head Squat	100.0%
	% of Total	100.0%

Each subscript letter denotes a subset of Over Head Squat categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.991[a]	4	.288
Likelihood Ratio	5.018	4	.285
Linear-by-Linear Association	2.827	1	.093
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.23.

Physical_activity_level * SL Hurdle

Crosstab

			SL Hurdle		
			1	2	3
Physical_activity_level	Above	Count	10a	59a	34b
		Expected Count	13.0	65.3	24.8
		% within Physical_activity_level	9.7%	57.3%	33.0%
		% within SL Hurdle	30.3%	35.5%	54.0%
		% of Total	3.8%	22.5%	13.0%
	Achieved	Count	9a	54a	19a
		Expected Count	10.3	52.0	19.7
		% within Physical_activity_level	11.0%	65.9%	23.2%
		% within SL Hurdle	27.3%	32.5%	30.2%
		% of Total	3.4%	20.6%	7.3%
	Below	Count	14a	53a	10b
		Expected Count	9.7	48.8	18.5
		% within Physical_activity_level	18.2%	68.8%	13.0%
		% within SL Hurdle	42.4%	31.9%	15.9%
		% of Total	5.3%	20.2%	3.8%
Total		Count	33	166	63
		Expected Count	33.0	166.0	63.0
		% within Physical_activity_level	12.6%	63.4%	24.0%
		% within SL Hurdle	100.0%	100.0%	100.0%
		% of Total	12.6%	63.4%	24.0%

Crosstab

			Total
Physical_activity_level	Above	Count	103
		Expected Count	103.0
		% within Physical_activity_level	100.0%
		% within SL Hurdle	39.3%
		% of Total	39.3%
	Achieved	Count	82
		Expected Count	82.0
		% within Physical_activity_level	100.0%
		% within SL Hurdle	31.3%
		% of Total	31.3%
	Below	Count	77
		Expected Count	77.0
		% within Physical_activity_level	100.0%
		% within SL Hurdle	29.4%
		% of Total	29.4%
Total		Count	262
		Expected Count	262.0
		% within Physical_activity_level	100.0%
		% within SL Hurdle	100.0%
		% of Total	100.0%

Each subscript letter denotes a subset of SL Hurdle categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	11.189[a]	4	.025
Likelihood Ratio	11.465	4	.022
Linear-by-Linear Association	9.951	1	.002
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 9.70.

Physical_activity_level * Split Squat

Crosstab

			Split Squat		
			1	2	3
Physical_activity_level	Above	Count	6a, b	32b	65a
		Expected Count	9.0	38.5	55.4
		% within Physical_activity_level	5.8%	31.1%	63.1%
		% within Split Squat	26.1%	32.7%	46.1%
		% of Total	2.3%	12.2%	24.8%
	Achieved	Count	7a	36a	39a
		Expected Count	7.2	30.7	44.1
		% within Physical_activity_level	8.5%	43.9%	47.6%
		% within Split Squat	30.4%	36.7%	27.7%
		% of Total	2.7%	13.7%	14.9%
	Below	Count	10a	30a	37a
		Expected Count	6.8	28.8	41.4

Crosstab

			Total
Physical_activity_level	Above	Count	103
		Expected Count	103.0
		% within Physical_activity_level	100.0%
		% within Split Squat	39.3%
		% of Total	39.3%
	Achieved	Count	82
		Expected Count	82.0
		% within Physical_activity_level	100.0%
		% within Split Squat	31.3%
		% of Total	31.3%
	Below	Count	77
		Expected Count	77.0

Crosstab

		Split Squat		
		1	2	3
	% within Physical_activity_level	13.0%	39.0%	48.1%
	% within Split Squat	43.5%	30.6%	26.2%
	% of Total	3.8%	11.5%	14.1%
Total	Count	23	98	141
	Expected Count	23.0	98.0	141.0
	% within Physical_activity_level	8.8%	37.4%	53.8%
	% within Split Squat	100.0%	100.0%	100.0%
	% of Total	8.8%	37.4%	53.8%

Crosstab

		Total
	% within Physical_activity_level	100.0%
	% within Split Squat	29.4%
	% of Total	29.4%
Total	Count	262
	Expected Count	262.0
	% within Physical_activity_level	100.0%
	% within Split Squat	100.0%
	% of Total	100.0%

Each subscript letter denotes a subset of Split Squat categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.387[a]	4	.117
Likelihood Ratio	7.298	4	.121
Linear-by-Linear Association	5.463	1	.019
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.76.

Physical_activity_level * Shoulder Mobility

Crosstab

			Shoulder Mobility		
			1	2	3
Physical_activity_level	Above	Count	5[a]	40[b]	58[b]
		Expected Count	9.8	37.7	55.4
		% within Physical_activity_level	4.9%	38.8%	56.3%
		% within Shoulder Mobility	20.0%	41.7%	41.1%
		% of Total	1.9%	15.3%	22.1%
	Achieved	Count	10[a]	24[a]	48[a]
		Expected Count	7.8	30.0	44.1
		% within Physical_activity_level	12.2%	29.3%	58.5%
		% within Shoulder Mobility	40.0%	25.0%	34.0%
		% of Total	3.8%	9.2%	18.3%
	Below	Count	10[a]	32[a]	35[a]
		Expected Count	7.3	28.2	41.4
		% within Physical_activity_level	13.0%	41.6%	45.5%
		% within Shoulder Mobility	40.0%	33.3%	24.8%
		% of Total	3.8%	12.2%	13.4%
Total		Count	25	96	141
		Expected Count	25.0	96.0	141.0
		% within Physical_activity_level	9.5%	36.6%	53.8%
		% within Shoulder Mobility	100.0%	100.0%	100.0%
		% of Total	9.5%	36.6%	53.8%

Crosstab

			Total
Physical_activity_level	Above	Count	103
		Expected Count	103.0
		% within Physical_activity_level	100.0%
		% within Shoulder Mobility	39.3%
		% of Total	39.3%
	Achieved	Count	82
		Expected Count	82.0
		% within Physical_activity_level	100.0%
		% within Shoulder Mobility	31.3%
		% of Total	31.3%
	Below	Count	77
		Expected Count	77.0
		% within Physical_activity_level	100.0%
		% within Shoulder Mobility	29.4%
		% of Total	29.4%
Total		Count	262
		Expected Count	262.0
		% within Physical_activity_level	100.0%
		% within Shoulder Mobility	100.0%
		% of Total	100.0%

Each subscript letter denotes a subset of Shoulder Mobility categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.253[a]	4	.123
Likelihood Ratio	7.744	4	.101
Linear-by-Linear Association	3.489	1	.062
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.35.

Physical_activity_level * Asymetric Leg Raise

Crosstab

			Asymetric Leg Raise		
			1	2	3
Physical_activity_level	Above	Count	12a	39a	52a
		Expected Count	11.0	45.2	46.8
		% within Physical_activity_level	11.7%	37.9%	50.5%
		% within Asymetric Leg Raise	42.9%	33.9%	43.7%
		% of Total	4.6%	14.9%	19.8%
	Achieved	Count	9a	37a	36a
		Expected Count	8.8	36.0	37.2
		% within Physical_activity_level	11.0%	45.1%	43.9%
		% within Asymetric Leg Raise	32.1%	32.2%	30.3%
		% of Total	3.4%	14.1%	13.7%
	Below	Count	7a	39a	31a
		Expected Count	8.2	33.8	35.0

Crosstab

			Total
Physical_activity_level	Above	Count	103
		Expected Count	103.0
		% within Physical_activity_level	100.0%
		% within Asymetric Leg Raise	39.3%
		% of Total	39.3%
	Achieved	Count	82
		Expected Count	82.0
		% within Physical_activity_level	100.0%
		% within Asymetric Leg Raise	31.3%
		% of Total	31.3%
	Below	Count	77
		Expected Count	77.0

Crosstab

		Asymetric Leg Raise		
		1	2	3
	% within Physical_activity_level	9.1%	50.6%	40.3%
	% within Asymetric Leg Raise	25.0%	33.9%	26.1%
	% of Total	2.7%	14.9%	11.8%
Total	Count	28	115	119
	Expected Count	28.0	115.0	119.0
	% within Physical_activity_level	10.7%	43.9%	45.4%
	% within Asymetric Leg Raise	100.0%	100.0%	100.0%
	% of Total	10.7%	43.9%	45.4%

Crosstab

		Total
	% within Physical_activity_level	100.0%
	% within Asymetric Leg Raise	29.4%
	% of Total	29.4%
Total	Count	262
	Expected Count	262.0
	% within Physical_activity_level	100.0%
	% within Asymetric Leg Raise	100.0%
	% of Total	100.0%

Each subscript letter denotes a subset of Asymetric Leg Raise categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.036[a]	4	.552
Likelihood Ratio	3.045	4	.550
Linear-by-Linear Association	.619	1	.431
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.23.

Physical_activity_level * Stability Push Up

Crosstab

			Stability Push Up		
			1	2	3
Physical_activity_level	Above	Count	4a	22a	77b
		Expected Count	11.8	27.9	63.3
		% within Physical_activity_level	3.9%	21.4%	74.8%
		% within Stability Push Up	13.3%	31.0%	47.8%
		% of Total	1.5%	8.4%	29.4%
	Achieved	Count	12a	20a	50a
		Expected Count	9.4	22.2	50.4
		% within Physical_activity_level	14.6%	24.4%	61.0%
		% within Stability Push Up	40.0%	28.2%	31.1%
		% of Total	4.6%	7.6%	19.1%
	Below	Count	14a	29a	34b
		Expected Count	8.8	20.9	47.3
		% within Physical_activity_level	18.2%	37.7%	44.2%
		% within Stability Push Up	46.7%	40.8%	21.1%
		% of Total	5.3%	11.1%	13.0%
Total		Count	30	71	161
		Expected Count	30.0	71.0	161.0
		% within Physical_activity_level	11.5%	27.1%	61.5%
		% within Stability Push Up	100.0%	100.0%	100.0%
		% of Total	11.5%	27.1%	61.5%

Crosstab

			Total
Physical_activity_level	Above	Count	103
		Expected Count	103.0
		% within Physical_activity_level	100.0%
		% within Stability Push Up	39.3%
		% of Total	39.3%
	Achieved	Count	82
		Expected Count	82.0
		% within Physical_activity_level	100.0%
		% within Stability Push Up	31.3%
		% of Total	31.3%
	Below	Count	77
		Expected Count	77.0
		% within Physical_activity_level	100.0%
		% within Stability Push Up	29.4%
		% of Total	29.4%
Total		Count	262
		Expected Count	262.0
		% within Physical_activity_level	100.0%
		% within Stability Push Up	100.0%
		% of Total	100.0%

Each subscript letter denotes a subset of Stability Push Up categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	20.287[a]	4	.000
Likelihood Ratio	21.527	4	.000
Linear-by-Linear Association	18.755	1	.000
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.82.

Physical_activity_level * Seated Rotation

Crosstab

			Seated Rotation		
			1	2	3
Physical_activity_level	Above	Count	19a	64a	20a
		Expected Count	19.3	66.8	16.9
		% within Physical_activity_level	18.4%	62.1%	19.4%
		% within Seated Rotation	38.8%	37.6%	46.5%
		% of Total	7.3%	24.4%	7.6%
	Achieved	Count	16a	50a	16a
		Expected Count	15.3	53.2	13.5
		% within Physical_activity_level	19.5%	61.0%	19.5%
		% within Seated Rotation	32.7%	29.4%	37.2%
		% of Total	6.1%	19.1%	6.1%
	Below	Count	14a, b	56b	7a
		Expected Count	14.4	50.0	12.6

Crosstab

			Total
Physical_activity_level	Above	Count	103
		Expected Count	103.0
		% within Physical_activity_level	100.0%
		% within Seated Rotation	39.3%
		% of Total	39.3%
	Achieved	Count	82
		Expected Count	82.0
		% within Physical_activity_level	100.0%
		% within Seated Rotation	31.3%
		% of Total	31.3%
	Below	Count	77
		Expected Count	77.0

Crosstab

		Seated Rotation		
		1	2	3
	% within Physical_activity_level	18.2%	72.7%	9.1%
	% within Seated Rotation	28.6%	32.9%	16.3%
	% of Total	5.3%	21.4%	2.7%
Total	Count	49	170	43
	Expected Count	49.0	170.0	43.0
	% within Physical_activity_level	18.7%	64.9%	16.4%
	% within Seated Rotation	100.0%	100.0%	100.0%
	% of Total	18.7%	64.9%	16.4%

Crosstab

		Total
	% within Physical_activity_level	100.0%
	% within Seated Rotation	29.4%
	% of Total	29.4%
Total	Count	262
	Expected Count	262.0
	% within Physical_activity_level	100.0%
	% within Seated Rotation	100.0%
	% of Total	100.0%

Each subscript letter denotes a subset of Seated Rotation categories whose column proportions do not differ significantly from each other at the .05 level.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.648[a]	4	.325
Likelihood Ratio	5.056	4	.282
Linear-by-Linear Association	1.183	1	.277
N of Valid Cases	262		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.64.