

**An investigation of the relationship between the Y-Balance Test
and the Sit-to-Raise-Test in a sample of active healthy adults:
A cross-sectional correlation design**

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of
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Declaration

Name of candidate: Attila Kruchio

This thesis entitled: “An investigation of the relationship between the Y-Balance Test and the Sit-to-Raise-Test in a sample of active healthy adults: A cross-sectional correlation design.” is submitted in partial fulfillment of the requirements for the Unitec degree of Master of Osteopathy.

Candidates Declaration

I confirm that:

- This thesis represents my own work;
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: UREC 2015-1036

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Date:

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1 ABBREVIATIONS

ACL = Anterior cruciate ligament

CAI = Chronic ankle instability

FTA = Functional turnout angle

PA = Physical activity

PPE = Pre-participation evaluation

PFPS = Patellofemoral pain syndrome

ROM = Range of movement

SEBT = Star Excursion Balance Test

SRT = Sit to Raise Test

YBT = Y-Balance test

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5 PREFACE

The role of physical activity in health has attracted considerable research and media attention. An essential part of living a physically active lifestyle involves being able to continue with participation in physical activity. Therefore, loss of participation that results from physical activity related injury is undesirable and can deprive an injured person from the benefits of participation including physical and mental health and related health benefits across the lifespan (Reiner, Niermann, Jekauc, & Woll, 2013). Drawing on the injury etiology model of Meeuwisse, Tyreman, Hagel, and Emery (2007) that identifies several intrinsic risk factors such as flexibility and neuromuscular control, researchers in the field of sports medicine have developed several different tools to help with pre-participation evaluation of movement.

The fundamental role of physical activity for health has been convincingly demonstrated in many studies and is central to the health initiatives in many countries (Reiner et al., 2013; Schoenborn & Stommel, 2011; US Physical Activity Guidelines Advisory Committee, 2016). There is a strong relationship between physical fitness and healthy aging, and the maintenance of joint mobility, balance, and muscle strength are indicators of morbidity (De Brito et al., 2012). In light of the relationship between physical health and ageing, Brazilian researchers developed a test called Sitting-Raising test, or ‘SRT’ that may provide a measure of musculoskeletal health. De Brito et al (2012) demonstrated that in older adults superior performance on the SRT was associated with lower all-cause mortality.

On the other hand, the Y-balance test was developed by Pliskey et al (2009) following research investigating the Star Excursion Balance Test ability to predict injury in an athletic population (Pliskey et al., 2006). The Y-Balance test (YBT) and Sitting-Raising test (SRT) are both attractive field expedient assessments that could be easily implemented for pre-participation evaluation (PPE) purposes. The YBT and SRT tests originate in two distinctly different populations with the YBT often implemented as a screening or rehabilitative outcome measure for competitive and recreational athletes, while the SRT originates from a general health perspective particularly in older adults. However, to some extent, it appears that the YBT and SRT share similar requirements in terms of physical qualities that are needed to perform them to an adequate level (balance, joint mobility, lower extremity and core strength). To date, no studies have compared performance between these two movement tests. Further, there is little reference information available that describes reference ranges of adults on the SRT.

Therefore, this thesis aims (1) to determine the strength of association between SRT and YBT scores, (2) to determine the strength of association between participant characteristics (age, weight, height, gender, activity level, self-reported physical health), SRT, and YBT scores; and (3) to generate preliminary reference data, including floor and ceiling effects, and convergent validity for both of these tests in a healthy, active adult population.

The structure of the thesis is arranged in three sections. Section 1, is dedicated to a Literature review with the following outline. Firstly, it focuses on physical activity and its many health benefits while acknowledging that alongside its numerous benefits also comes the risk of physical activity-related injury. This is followed by an introduction and detailed discussion of the current, relevant literature available for the Y-balance test, followed by the available literature discussing the Sitting-Raising test. This will be followed by a comparison of measurement properties of these two tests, before a summary of ‘gaps’ in knowledge provide a rationale for a study reported in Section 2. The study purposefully targeted physically active people to provide, within the constraints of a 90 credit thesis, reference data about SRT and YBT performance in physically active adults (which has not been previously reported). Section 3 Appendices including ethics documentation and other supportive material.

6 PHYSICAL ACTIVITY AND HEALTH, AN INTRODUCTION

A physically active lifestyle can have substantial long-term health benefits, for example, even minimal adherence to the physical activity guidelines is associated with a substantial 20-30% reduction in risk of all-cause mortality (I.-M. Lee & Skerrett, 2001). Unfortunately, alongside the health benefits, the risk of injury is an outcome of increased physical activity levels (Hootman et al., 2001). Clinicians from all health disciplines have a duty of care to identify individuals who may be at risk of preventable injuries that are associated with physical activity. Additionally, practitioners need to assist patients with informed decision making in pursuing a physically active lifestyle. Injuries create an emotional and financial burden to physically active people, athletes, their families, sporting organizations, and government agencies (ACC, 2016; Air, 2013). In New Zealand, the Accident Compensation Commission (ACC) reported over 18,700 entitlement claims between July 2014 to June 2015, from sport-related injuries alone (ACC, 2016). While the exact number of entitlement injuries sustained by non-contact related incidents is not supplied by ACC, the number of total sporting entitlement claims suggest a sizeable portion. An unfortunate outcome of musculoskeletal injury is that there is an association with decreased future physical activity levels (Beckenkamp, Lin, Engelen, & Moseley, 2016). The reduced physical activity levels that follow a musculoskeletal injury can be observed even 12 months after the initial injury event, even when the person has no physical disability as a result of the injury sustained 12 months earlier (Andrew et al., 2014). The far-reaching implications of the negative impact of injury on physical activity levels are especially relevant considering the strong evidence for the inverse dose-response relationship between the amount of physical activity performed and the subsequent decrease in all-cause mortality rates (I.-M. Lee & Skerrett, 2001).

6.1 THE MANY FAVORABLE, AND SOME UNWANTED OUTCOMES OF PHYSICAL ACTIVITY

Indeed, regular physical activity has favorable effects on a wide range of noncommunicable diseases such as cardiovascular, diabetes, hypertension, mental health (including) depression, some types of cancer, and osteoporosis (Warburton, Nicol, & Bredin, 2006). Table 1 summarizes the health benefits of an active lifestyle in children and adults as reported by the United States Physical Activity Guidelines Advisory Committee (US Physical Activity Guidelines Advisory Committee, 2016). The clear and wide-ranging health benefits of physical activity have become major drivers for publically funded physical activity promotion initiatives.

TABLE 1: The health benefits of physical activity for adults and children.
Redrawn from the work of Martin-Diener, Brügger and Martin (2010).

Health benefits of physical activity			
In adults		In children	
Increases	Decreases	Increases	Decreases
↑ Life expectancy	↓ Coronary heart disease	↑ Physical fitness	↓ Body fatness
↑ Cardio-respiratory fitness	↓ High blood pressure	↑ Cardiorespiratory endurance	↓ Anxiety symptoms
↑ Muscular fitness	↓ Stroke	↑ Muscular strength	↓ Depression symptoms
↑ Healthy body mass	↓ Diabetes type 2	↑ Health status	
↑ Healthy body composition	↓ Metabolic syndrome	↑ Favorable cardio-vascular risk profile	
↑ Bone health	↓ Colon cancer	↑ Favorable metabolic disease risk profile	
↑ Sleep quality <i>(Modest evidence)</i>	↓ Breast cancer	↑ Bone health	
↑ Health-related quality of life <i>(Modest evidence)</i>	↓ Depression		
Additionally in older adults	↓ Risk of falling		
↑ Functional health			
↑ Cognitive function			

6.2 GOVERNMENT INITIATIVE FOR INCREASED PHYSICAL ACTIVITY

Attempts to increase physical activity levels in New Zealand received a significant push during the last decade with public health initiatives such as Green Prescription (Ministry of Health, 2014), and the Push Play campaign (Green, 2013). The Push Play campaign aimed at encouraging people between 25 to 50 years to become more active and commit themselves to at least 30 minutes of daily physical activity (Green, 2013). Similarly, Green prescription is an initiative where general practitioners advise at-risk patients to increase physical activity levels as a preventative measure against medical conditions that are closely associated with inactivity (Ministry of Health, 2014). It is predicted that referrals of adult patients alone will reach 68,000 in total by the end of 2017 (Ministry of Health, 2014). The Green Prescription general guideline for New Zealand adults calls for “sitting less and moving more”, achieving at least 2.5 hours of moderate or 1.25 hours of vigorous physical activity spread throughout the week, with at least two weekly sessions aimed at improving muscle strength. In addition, the New Zealand Ministry of Health advises that for extra health benefits, people should aim for 5 hours of moderate or 2.5 hours of vigorous physical activity spread throughout the week (Ministry of Health, 2015). While the benefits of an active lifestyle are undeniable, it is well established that a clear relationship exists between increased activity levels and injury risk. Simply stated, an increased exposure to physical activity leads to higher numbers of activity-related injuries (Martin-Diener, Brügger, & Martin, 2010). Consideration for the increased level of physical activity and its potential for negative outcomes must be considered in the context of public health because non-participation due to injury can lead to a lifelong reduction of activity levels or the potential outcome it may have on performing activities associated with daily living, and thus, negatively impacting on quality of life (Finch & Cassell, 2006).

6.3 THE DYNAMICS OF INCREASED PHYSICAL ACTIVITY LEVEL AND INJURY RISK

Studies investigating the relationship between activity level and injury risk show that the threat of activity-related injury increases with greater participation (Hootman et al., 2001; Morrow Jr, DeFina, Leonard, Trudelle-Jackson, & Custodio, 2012). For example, Hootman et al (2001) reported data from their prospective epidemiologic study of 5,000 people that those who spend more (compared to less) than 1.25 hours per week being active, are runners (compared to non-runners) (Men: odds ratio [OR] 2.38, 95% CI 1.87, 3.04; Women: OR =

1.68, 95% CI 1.03, 2.74) , participate in a sport (compared to no participation), or have a moderate to high cardiorespiratory fitness level (compared to less than moderate) (Men moderate: OR = 2.35, 95% CI 1.50, 3.70) (Men high: OR = 3.99, 95% CI 2.58, 6.18) (Women moderate: odds ratio 1.26, 95% CI 0.61, 2.58) (Women high: OR = 1.78, 95% CI 0.88, 3.58) were more likely to sustain an injury related to physical activity (Hootman et al., 2001). Furthermore, Hootman et al. (2001) suggested that the link between cardiorespiratory fitness and increased level of exercise-related injuries points to exercise intensity as a possible factor in exercise related injury rates since amongst walkers an increase in time spent walking was not associated with an increased risk of injury. More recently Morrow Jr et al. (2012) investigated the relationship between activity level and injury rate in a population of community-dwelling women and found an increased risk of activity-related injury that correlated with the increased amounts of physical activity performed. Given the relationship between increasing physical activity and injury risk, in an editorial directed to sports and exercise medicine practitioners, Verhagen, Bolling, and Finch (2015) highlighted the need for practitioners and researchers to be more proactive about the prevention of activity-related injury. Further, Verhagen et al. (2015) have argued strongly for employing evidence-based injury prevention strategies alongside the now common physical activity prescription guidelines produced by many agencies.

6.4 PHYSICAL ACTIVITY PROMOTION IN THE ELDERLY POPULATION

When it comes to the elderly population at risk of falling, there is good evidence for the benefits of physical activity outweighing the risk of injury when low impact physical activities that help to gain muscle strength and balance are prescribed as part of an activity routine (Martin-Diener et al., 2010; Robertson, Campbell, Gardner, & Devlin, 2002; Shubert, 2011). A literature review by Shubert (2011) concluded that effective interventions to manage fall risk have incorporated structured progression, were adjusted to the specific and current physical abilities of the person, and reached a minimum level of optimal dose and duration so that the person's physical abilities can adapt to the particular exercise intervention (Shubert, 2011).

Additionally, a study by Robertson et al. (2002) on injury prevention in the elderly by preventing falls, investigated the data of more than 1000 elderly people aged 80 or more who followed an individually-prescribed and supervised program aimed at strength and balance improvement in their home settings. Robertson et al. (2002) found that, in both males and females, the specific physical activities prescribed were effective at reducing falls in those with or without the incident of a previous fall (Robertson et al., 2002). Robertson et al. (2002) stated that meta-analysis of the data showed that the specific, individually tailored home exercise program reduced both falls and fall-related injuries in community-living older people by 35%.

6.5 WHAT IS AN INJURY

The definition of what does, and what does not constitute an injury is contentious. In the absence of a clear, widely accepted definition for what constitutes an injury, screening methods aimed at preventing them become a complex and challenging issue. Indeed, the definition used to identify an injury can have a wide-ranging effect on research findings, and on the development of injury prevention strategies or programs that follow the research (Fuller, 2010). Previous studies investigating sport injuries in the context of pre-participation screening for possible risk factors have used a varying range of definitions. For example, in their study of movement competency based on Functional Movement Screen (FMS) results as an injury risk factor in female collegiate athletes Chorba, Chorba, Bouillon, Overmyer, and Landis (2010) defined injury using a 'medical attention' definition, while in their investigation of an injury screening algorithm incorporating YBT and FMS findings, authors Lehr et al. (2013) defined injury using a combination of both 'medical attention' and 'time loss' definitions. A third example using a different definition is Butler et al. (2013) who investigated FMS as a risk factor in firefighters and used only a 'time loss' definition. These three examples of differences in injury definition between studies investigating the same field highlights the ambiguity issues that Fuller et al (2010) have identified as being undesirable because of its potential for a ripple effect on injury classification, and epidemiology (Fuller, 2010). A sporting injury definition that has been gaining general acceptance in injury prevention research in several sports is the consensus statement for football (soccer) (Fuller, 2010).

This definition defines injury as “Any physical complaint (caused by a transfer of energy that exceeds the body’s ability to maintain its structural and/or functional integrity) sustained by an athlete during competition or training directly related to the sport or exercise investigated, irrespective of the need of medical attention or time-loss from athletic activity.” (Fuller, 2010).

6.6 INJURY RISK FACTORS, AND ETIOLOGY OF INJURY

A model demonstrating the etiology of injury is necessary to help the understanding of the contributing factors that may act alone or together as predisposing factors to injury (Figure 1). The main model outlining the etiology of injury was developed by Meeuwisse et al. (2007) and provides a comprehensive view stating that risk for injury during intense physical activity is dynamic in nature, and changes with ongoing involvement. This model points out that injury risk factor can be grouped into two major categories, firstly those that are ‘extrinsic’ to the individual (characteristics of the environment or type of activity participated in), and secondly ‘intrinsic’ (e.g: structural characteristic of player like size, age, strength, emotional state) (Meeuwisse et al., 2007). In addition to intrinsic and extrinsic risk factors, Rose, Emery, and Meeuwisse (2008) point out that injuries can come about as the result of an inciting event (e.g. opponent behavior) during a competitive playing situation. This model recognizes that the nature of sports injury does not follow a step by step progression that is predictable in advance, and adaptations that might be favorable, or perhaps detrimental, occur during sports participation resulting in an altered risk of injury (Meeuwisse et al., 2007). Indeed, sports injuries come about as the result of the ever changing dynamic set of “shifting circumstances”, thus injury prevention strategies need to look beyond the initial set of risk factors and take into account how they may change with each cycle of sports participation (Meeuwisse et al., 2007).

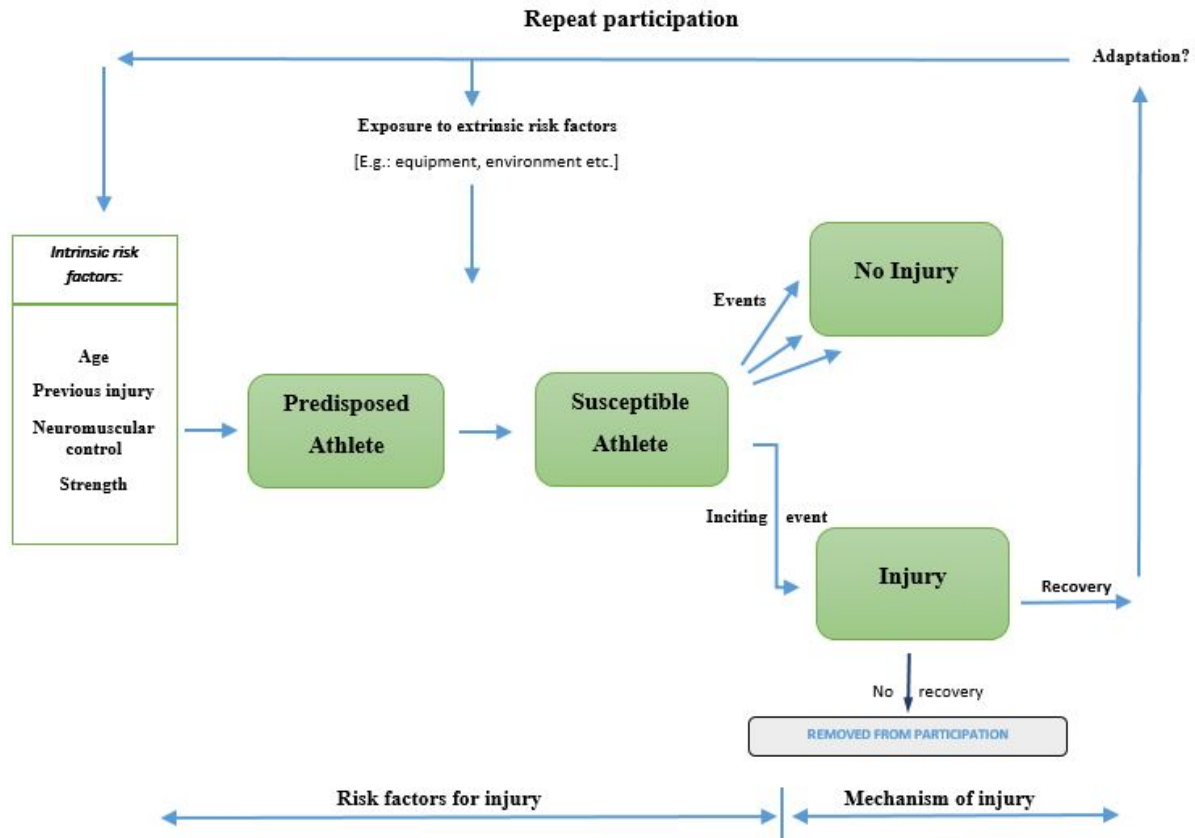


FIGURE 1 THE DYNAMIC, RECURSIVE MODEL OF ETIOLOGY IN SPORTS INJURY.
Redrawn from the work of Meeuwisse et al (2007).

It is important to note that some risk factors are modifiable, some considered to be potentially modifiable (e.g: attitude for risk taking behavior), but other factors such as an existing history of a previously sustained injury are considered to be non-modifiable (Rose et al., 2008). The importance of modifiable risk factors is that they are responsive to intervention and so identifying these modifiable factors is valuable when trying to prevent injury (Cameron, 2010). For example, if a known modifiable risk factor, such as muscle strength deficit, is detected (Khayambashi, Ghoddosi, Straub, & Powers, 2015; Nicholas & Tyler, 2002; Stege, Dallinga, Benjaminse, & Lemmink, 2014) a person's physical activity or training could be modified and a specific training program designed to address this strength deficit.

Further to identification of known modifiable risk factors, non-modifiable risk factors provide the clinician with additional information about a population that is prone to injury therefore, providing valuable background information for informed risk assessment (by the practitioner) and the decision (by the athlete) to participate in a particular sporting event or sporting activity (Cameron, 2010).

6.7 PREVENTATIVE MEASURES

Many sports injuries have been traditionally labeled and associated with a specific sporting activity commonly involved, giving rise to lay terminology such as jumper's knee, golfer's or tennis elbow (van Mechelen, Hlobil, & Kemper, 1992). This labeling may give the initial impression that a generalized prevention effort aimed at recreational and sporting activities is unlikely to be of value since injuries might be too specific to certain sports. For example, this logic would imply that tennis elbow could only occur in people who play tennis. In practice, these conditions frequently occur in people with jobs and recreational activities involving repetitive manual tasks or athletes (from various sporting backgrounds) who are exposed to prolonged weight bearing activities (Jariwala, Dorman, Bruce, & Rickhuss, 2012). Therefore, van Mechelen et al (1992) make the suggestion that activities where similar injuries frequently occur could be grouped together, and a similar preventative effort could be implemented in order to reduce injury risk associated with these activities. To provide a framework from which to consider research sports injury prevention research, van Mechelen et al (1992), offers a four-step prevention model that groups research activities into (1) identification of the problem, (2) mechanisms behind it, (3) preventative measures applied and (4) evaluating their effectiveness (van Mechelen et al., 1992).

6.8 PRE-PARTICIPATION EVALUATION, AND ITS PLACE IN THE FOUR-STEP MODEL

The pre-participation physical evaluation (PPE) is widely practiced in the United States and commonly undertaken by both amateur and professional athletes in order to investigate cardiovascular and musculoskeletal health prior to the athletic season (Mirabelli, Devine, Singh, & Mendoza, 2015). Benefits of PPE from a musculoskeletal point of view include (i) enhancing the practitioner's ability to gather information about areas of the body that might be affected by pain, or stiffness; (ii) presenting an opportunity for the assessment of

previously sustained injuries and (iii) highlighting current flexibility, strength deficit or biomechanical factors that may predispose the athlete to injury (Grant, 1997). The value of PPE for physically active people or those who are about to go from a sedentary lifestyle to an active one is significant. PPE provides one of the few occasions in which a practitioner might have an opportunity to evaluate a person for a known modifiable risk factor, thus enabling appropriate intervention and potentially improving the odds of minimizing injury risk. Indeed, modern scientifically based injury prevention strategies can be viewed against van Mechelen et al's (1987) four step "sequence of prevention" model. Within this model, the practice of PPE fits in the third step, by screening those that are ready to increase, take up, or return to physical activity after a previous injury. See Figure 2.

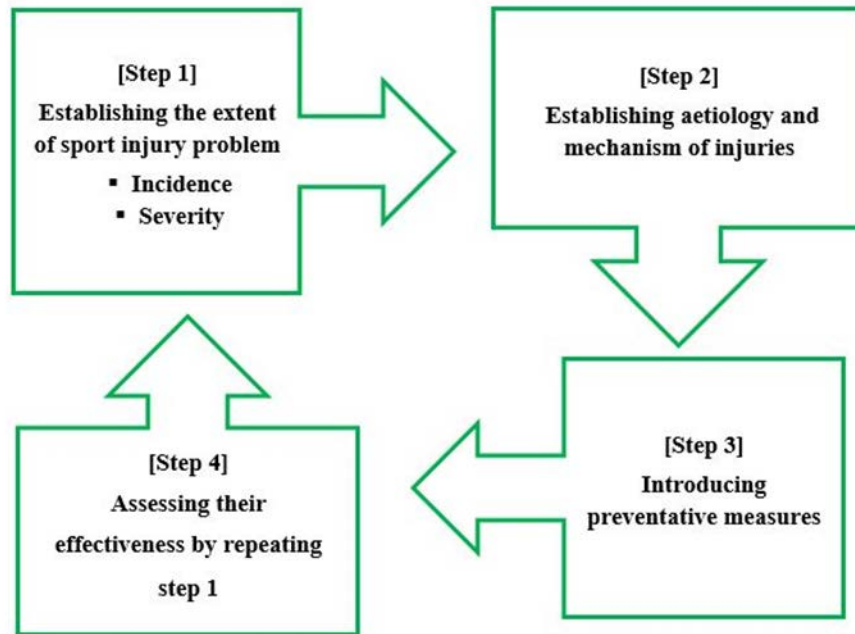


FIGURE 2 SEQUENCE OF PREVENTION MODEL.

Redrawn from the work of van Mechelen et al (1992).

However, in many real-world situations when time or other resources become a limiting factor it might not be feasible to individually test for each of the known intrinsic risk factors. While intrinsic risk factors can be identified in laboratory settings with complex three-dimensional motion analysis representing the gold standard for researching biomechanical patterns, they have very limited utility in field settings. Consequently, several field-based screening tests aimed at known intrinsic risk factors such as postural control (Gribble, Hertel, & Plisky, 2012) and joint mobility (Heaton, Azuero, Phillips, Pickens, & Reed, 2012) have been described. The YBT and SRT are examples of simple, clinically applicable, field-expedient low-cost test alternatives to the more sophisticated and expensive laboratory testing instruments.

7 OVERVIEW AND DESCRIPTION OF THE Y-BALANCE AND SITTING-RAISING TESTS

The Y-balance test was developed by Pliskey et al (2009) following research investigating the Star Excursion Balance Test (Pliskey et al., 2006). Because of the extensive similarities between SEBT and YBT, research related to SEBT has been integrated into this section.

Within this chapter, following a short overview of the YBT development, reliability, validity and its ability to be an outcome measure will be discussed. Additionally, in the later part of this section, the literature review will introduce, overview and discuss the development of the Sitting-Raising Test (SRT).

7.1 A SHORT OVERVIEW OF THE YBT

The SEBT originated as a lower extremity rehabilitative tool (Gribble et al., 2012), but was embraced by researchers and clinicians as a diagnostic screening tool to identify dynamic balance deficits, predict the risk of future lower extremity injury, and help decision making for returning to sport readiness (Gribble et al., 2012). While the original version of SEBT called for eight different reach directions, a factor analysis by Hertel, Braham, Hale, and Olmsted-Kramer (2006) showed that there was some redundancy within some of these reach directions. The findings of Hertel et al (2006) were subsequently reinforced by other researchers looking at the similarities between captured information related to the posteromedial or posterolateral reach aspects of either test (Coughlan et al., 2012).

Researchers investigating possible improvements of efficiency in the administration of the SEBT found that three of the original eight directions could be quickly and reliably performed on a large group of athletic population with little loss of information from using three instead of eight reach directions (Plisky, Rauh, Kaminski, & Underwood, 2006). Visual representation of the original eight SEBT directions and newly adopted YBT is shown in Figure 3. The apparent overlap indicated some redundancy of reach directions, and coupled with the development of the Y-balance test kit resulted in a resource that is relatively low tech and low cost and capable of capturing the same information as the SEBT while managing to address the common sources of error and method variation previously seen in SEBT (Plisky et al., 2009).

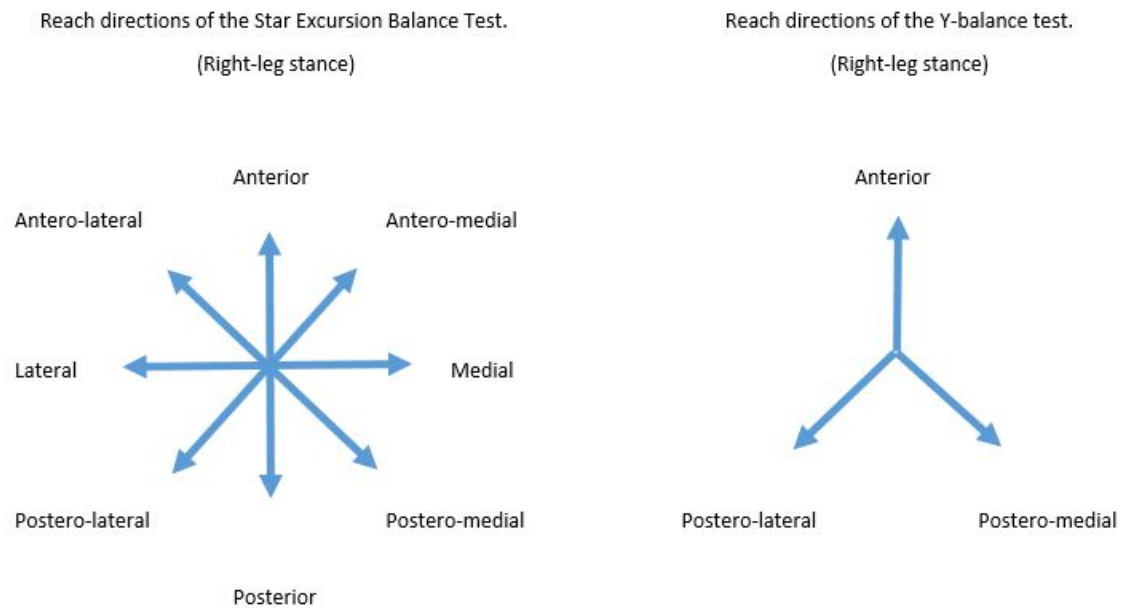


FIGURE 3 THE ORIGINAL 8 REACH DIRECTIONS OF SEBT, AND THE 3 REACH DIRECTIONS OF YBT

7.2 THE INSTRUMENTED Y-BALANCE AND STAR EXCURSION BALANCE TESTS

The chronological timeline of studies looking at SEBT and YBT reflects the development of these two movement screens as SEBT transforms from a time-consuming clinical diagnostic test into an instrumented version of the YBT that manages to address the common sources of error, and method variation previously associated with SEBT. In this section, the literature review will cover the reliability, validity of SEBT in addition to SEBT's ability to detect reach distance discrepancies, as well as its use as an outcome measure for exercise-based rehabilitation intervention.

7.3 RELIABILITY OF THE SEBT AND YBT

The earliest research investigating the reliability of SEBT scores was conducted by Kinzey and Armstrong (1998), and emphasized intra-rater consistency. Twenty healthy subjects between the ages of 18 and 35 years old were rated over two testing sessions, 7 days apart. The main finding was that the diagonal reach attempts of the posteromedial and posterolateral directions (these two identical reach directions are also included in the YBT) had good intra-class coefficient (ICC) values of 0.82 to 0.87 (confidence intervals not reported) (Kinzey & Armstrong, 1998). Following the timeline of SEBT's research and development, the next study, by Hertel, Miller, and Denegar et al (2000), explored intra and inter-rater reliability. In this research 16 healthy, active participants (n=8 males, n=8 females) performed twelve reach trials on each of two test days. There was good to excellent reliability with intra-rater ICCs of 0.85 to 0.95 on Day 1, and 0.85 to 0.96 on Day 2 of the three reach directions that are a part of the YBT (confidence intervals not reported) (Hertel et al, 2000). Inter-rater reliability findings indicated a range of fair to good on day one by inter-rater ICCs of 0.58 to 0.84, and good to excellent on day two by an inter-rater reliability ICC range of 0.86 to 0.93 for YBT directions (confidence intervals not reported) (Hertel et al., 2000). Additionally, this research suggested a significant learning effect in two directions that are part of YBT (posteromedial and posterolateral), prompting Hertel et al (2000) to recommended 6 practice trials in each direction prior to recording any reach distance values (Hertel et al., 2000).

The need to normalize reach distances by considering leg length arose from the findings of a study that investigated the impact of foot type, leg length, hip internal, external range of motion, and ankle dorsiflexion on SEBT reach distances (Gribble & Hertel, 2003). Gribble and Hertel (2003) found no significant correlations within foot type variety, or hip ROM, but observed significant and large correlations between height and excursion distance, as well as leg length and excursion distance ($p < 0.05^1$, $r = 0.89$), with the latter having the stronger correlation (Gribble & Hertel, 2003).

A study by Gribble, Kelly, and Hiller (2013) investigating the inter-rater reliability of SEBT conducted over two different testing sites by three different raters demonstrated good to

¹ Exact p values not reported

excellent inter-rater reliability (Gribble, Kelly, Refshauge, & Hiller, 2013). In this study reach distances normalized for leg length were associated with ICC coefficients ranging from 0.86 to 0.92, while reach distances not normalised for leg length were associated with ICC coefficients of 0.89 to 0.94, therefore displaying strong consistency within all three raters, independent of testing site in all three of the YBT reach directions (Gribble et al., 2013).

7.4 STUDIES IN SUPPORT OF REDUCED REACH DIRECTIONS

The most recent reliability study looking at the intra and inter-rater reliability of SEBT showed good to excellent intra-rater reliability for the anterior reach direction with an ICC value of 0.88 (CI 95%, 0.81–0.93), posteromedial ICC value of 0.94 (CI 95%, 0.91–0.97), and an ICC value of 0.93 (CI 95%, 0.88–0.96) for the posterolateral aspects of YBT reach directions (Hyong & Kim, 2014). Inter-rater reliability over three different raters for the anterior, posteromedial and posterolateral reach directions were 0.83 (CI 95%, 0.75–0.89), 0.90 (CI 95%, 0.85–0.94) and 0.88 (CI 95%, 0.82–0.92) respectively (Hyong & Kim, 2014). The findings of this study supported the previously debated idea of reducing the original eight reach directions of SEBT to just three reach directions in order to reduce time in test administration. The reduction of reach directions has been discussed in previous studies highlighting that some reach directions of the SEBT are redundant, while others like the posteromedial component of the SEBT remains highly representative of the performance of all eight reach directions of SEBT in limbs with, and without chronic ankle instability (CAI) (Hertel et al., 2006). Furthermore, the reduction of the number of reach directions considerably decreases set-up time, and the duration it takes to administer the test, thus making it more convenient and less fatiguing for the practitioners and patients.

7.5 THE Y-BALANCE TEST KIT AND PROTOCOL

The concluding developmental step of SEBT to YBT transformation occurred with the emergence of a commercially available Y Balance Test™ kit (FunctionalMovement.com, Danville, United States). The YBT kit and its protocol aim to diminish common causes of error and method variation in the SEBT and had shown good to excellent intra-rater reliability with composite ICC values of 0.89 (CI 95%, 0.69-0.96), and excellent inter-tester reliability with an ICC range of 0.97 to 1.00 (CI 95%, 0.96-0.99) (Plisky et al., 2009). For the suggestions made by Plisky et al (2009) to improve SBT protocols to improve inter-rater reliability refer to table 2.

Additional research conducted on the instrumented version of the YBT supports these findings and showed promising results for interrater reliability and measurement stability when rating actively training military service personnel (Shaffer et al., 2013). Shaffer et al. (2013) reported good interrater reliability (ICC values = 0.85-0.93) and acceptable measurement error values (SEM = 2.0-3.5 cm), and found that the interrater test-retest reliability for the maximal reach distance achieved good ICC values that ranged from 0.80 to 0.85 with an associated SEM ranging from 3.1 to 4.2 cm (Shaffer et al., 2013).

Finally, a study by Faigenbaum et al. (2014) investigated the feasibility and interrater reliability of the YBT in 188 children (aged 7 to 12 years old). In this study, 5 testing stations were used simultaneously. Additionally, two raters simultaneously observed test performance (observer error) over a single session of YBT performance on a subsample of 14 participants, and finally performance error was assessed by two different raters who scored 8 participants performing separate trials of the YBT-LQ for each rater on the same day. Faigenbaum et al. (2014) found interrater reliability (within session) ICCs for the YBT were excellent for observer error (ICC > 0.995, CI not reported), interrater reliability for performance error (within session, between trials) were excellent (ICCs = 0.907–0.990, CI not reported) (Faigenbaum et al., 2014).

TABLE 2: Recommendation made by Plisky et al (2009), for the administration of YBT in order to reduce measurement errors.

Recommendations made by Plisky, et al (2009):	Rationale for recommendations:
Shoes off.	Individuals attend testing in a variety of footwear so it is difficult to standardize.
Six practice trials.	Minimising learning effect.
Standard testing order.	Minimize fatigue by alternating stance limbs. Improves consistency in the administration of the test.
Stance foot aligned at the most distal aspect of toes.	Keeps starting point in a uniform and reproducible position to which the reach foot can be referenced.
Stance foot movement is allowed.	Difficult to reliably determine if heel/forefoot is lifted from the surface.
Body movement allowed under control.	Difficult to standardize the amount of movement allowed.
Normalized to limb length.	Normalization standardizes measurement to each individual.
Standard reach height.	Allows reach the height to be uniform.

7.6 SUMMARY OF SEBT AND YBT RELIABILITY

The studies investigating SEBT and YBT reliability have consistently found the intra-rater reliability of SEBT to be good to excellent (Hertel et al., 2000; Hyong & Kim, 2014; Kinzey & Armstrong, 1998), while the inter-rater reliability of SEBT has been found to be fair to excellent (Gribble et al., 2013; Hertel et al., 2000; Hyong & Kim, 2014). While studies concerned with intra and inter-rater reliability of the YBT have identified good to excellent levels in both aspects (Plisky et al., 2009; Shaffer et al., 2013).

7.7 VALIDITY OF THE SEBT AND YBT

In its early development, the SEBT was initially used as a rehabilitative tool for various pathologic conditions of the lower extremity (Gribble et al., 2012). However, the development of SEBT and YBT has led to its application in clinical or research settings for detection of certain pathologic conditions, the risk of injury, and evaluation of rehabilitative intervention protocols (Gribble et al., 2012).

7.8 PATHOLOGIC CONDITIONS AND SEBT REACH DISTANCE DISCREPANCIES

Reach distance discrepancies on SEBT have been associated with several lower extremity conditions including chronic ankle instability (CAI), anterior cruciate ligament (ACL) reconstruction, and patello-femoral pain syndrome (PFPS) (Gribble et al., 2012). The premise underlying SEBT application in the assessment of these conditions is that supporting body weight on the affected limb during single leg stance would produce a discrepancy in reach distance when compared to the uninjured side. A discrepancy in reach distance might potentially indicate a deficit in the dynamic postural control, consequently highlighting a need for further investigations (Gribble et al., 2012).

The importance of dynamic postural control in relation to a lateral ankle sprain and chronic ankle instability has been extensively investigated in a previous systemic review by McKeon and Hertel (2008). The outcome of this investigation by McKeon and Hertel (2008) prompted the authors to conclude that poor postural control is indeed associated with an increased risk of ankle sprain (McKeon & Hertel, 2008).

Furthermore, it has been suggested that clinical diagnosis of CAI based exclusively on force plate measurements might be a poor choice due to the static nature of testing, and there is a rationale to include SEBT as a better choice for diagnosing CAI since SEBT is more dynamic in nature thus more adept at challenging postural control deficiency seen in CAI (McKeon & Hertel, 2008).

The ability of SEBT to highlight CAI reach deficits has been clearly demonstrated between injured and non-injured limbs since subjects with CAI achieving significantly shorter reach distances with their injured lower limb (78.6 cm injured side versus 81.2 cm uninjured side) ($P < 0.05^2$) (Olmsted, Carcia, Hertel, & Shultz, 2002). Additionally, a similar reduction of reach distance was observed in subjects with injured limbs side-matched with an uninjured control group (78.6 cm versus 82.8 cm) (Olmsted et al., 2002). Follow-up investigations into SEBT reach directions and its relationship with CAI found deficits in the posteromedial, anteromedial and medial reach directions when compared to their uninvolved lower limb (Hertel et al., 2006).

Furthermore, a recent study by Pionnier et al (2016) used a motion capture system while participants with, and without CAI performed the SEBT. They found that CAI participants on average reached shorter distances (80% of leg length, $79.9 \pm 9.9\%$ of lower limb length) than healthy controls (85% of leg length, $84.7 \pm 7.6\%$ of lower limb length) for the 8 reach direction of SEBT (Pionnier, Découfour, Barbier, Popineau, & Simoneau-Buessinger, 2016). A secondary analysis of data captured for the directions of the YBT supported its use as an effective test for detecting reach deficits ($F_{1,32} = 5.331$, $p = 0.028$, CI not reported) in participants with CAI (Pionnier et al., 2016).

The capacity of SEBT to detect performance deficits related to pathology has also been investigated in a study evaluating any existing postural control deficits of ACL deficient participants (Herrington, Hatcher, Hatcher, & McNicholas, 2009). Herrington et al. (2009) compared SEBT reach distances (expressed as a percentage of participant's leg length) across 25 participants (17 male, 8 female) with complete ACL rupture to those of a control group of

² Exact p values not reported

25 that was matched for age, sex, activity type and level, found significant differences between the control group and the participants with ACL deficient limb in the following SEBT directions of anterior, lateral, posterior-medial and medial (Herrington et al., 2009). The implication of this is that “patients with ACL deficiency would appear to have deficits in their dynamic postural control when compared to normal asymptomatic subjects when attempting to balance on their injured leg” (Herrington et al., 2009), and SEBT was able to detect these deficits.

The SEBT has also attracted research interest in relation to its ability in identifying signs and symptoms associated with Patellofemoral Pain Syndrome. Research conducted in a sample of 20 participants (12 females, 8 males) with PPS, whom were on average 20 (± 1.87) years old, height of 170 cm (± 10.17 cm), weighing 71 kg (± 14.04 kg) indicated that SEBT’s anterior reach direction displays the most significant variances within participants with PFPS displaying a significantly longer anterior reach (0.7%) when having their patella taped ($P = 0.03$) when compared to their asymptomatic control group (Aminaka & Gribble, 2008).

The last research project covered in this literature review looked at pathologic conditions and SEBT reach distance discrepancies was published by Garrison, Arnold, Macko, and Conway (2013). Garrison, Arnold, Macko, and Conway (2013) compared the YBT scores of 30 healthy baseball players (mean age 19, $SD \pm 1.1$ years) with 30 baseball players (mean age 18.5, $SD \pm 1.9$ years) whom previously suffered an ulnar collateral ligament tear. Garrison, Arnold, Macko, and Conway (2013) found that baseball players with ulnar collateral ligament tears scored significantly lower on the YBT composite scores with both, non-dominant (mean $\pm SD$ 88.2% $\pm 7.9\%$) and their dominant limb (89.1% $\pm 6.7\%$) when compared to the uninjured control group (Non-dominant - mean 95.4% $\pm 6.4\%$, and dominant limb 95.8% $\pm 6.1\%$, $P < 0.001$) (Garrison et al., 2013). These findings prompted Garrison, Arnold, Macko, and Conway (2013) to recommend addressing balance deficits alongside shoulder ROM deficits in the preventative or rehabilitative efforts of ulnar collateral ligament tears in baseball players.

7.9 EXERCISE INTERVENTION AND SEBT AS AN OUTCOME MEASURE

A general goal of all musculoskeletal practitioners is to reduce lasting effects of injury by helping athletes to return to pre-injury activity levels. Research has demonstrated the discriminative ability of the SEBT in differentiating functional deficits not only in ankle pathologies such as CAI (Olmsted et al., 2002) but also knee pathologies including ACL deficiency (Herrington et al., 2009) and PFPS (Aminaka & Gribble, 2008). These findings prompted some authors to explore SEBT's applicability as a designated outcome measure to monitor exercise intervention effectiveness of known performance deficits. A search of the literature identifies two, four-week long studies that explored this hypothesis (Hale, Hertel, & Olmsted-Kramer, 2007; P. O. McKeon et al., 2008)

In the first prospective randomized control trial study by Hale et al. (2007), researchers implemented a protocol where participants were assigned to one of three groups; (1) a CAI group who performed the exercises, or (2) a healthy matched control group who also performed the weekly supervised rehabilitative routine, or (3) another CAI group who did not perform the exercises. In addition to the supervised sessions, the participants who were assigned to the exercise groups were also provided a home exercise program to perform five times each week on their own. The results indicated outcome improvements in participants from the exercise intervention CAI group when compared with the healthy control group, and the CAI group who did not perform the training program (Hale et al., 2007). Changes were detected in the posteromedial ($P = 0.03$), posterolateral ($P = 0.01$), and lateral ($P = 0.009$) and composite score of all 8 directions ($P = 0.03$) (Hale et al., 2007). In addition to these findings, the second study (randomized controlled trial) established similar outcomes following four weeks of progressive, supervised training program that consisted twelve, 20 minutes of supervised training. At the same time the control group was instructed to maintain the same level of physical activity that they already performed prior to volunteering (P. McKeon et al., 2008). In this study McKeon et al (2008) also noted a positive outcome on the posteromedial ($P=0.01$) and posterolateral ($P=0.03$) reach directions .

7.10 IDENTIFICATION OF YBT DEFICITS

A search of the ACC injury database using the publicly accessible injury statistics tool (<http://www.acc.co.nz/about-acc/statistics/injury-statistics-tool/index.htm#>) by claim type (entitlement), injury sites (ankle, knee, lower leg), causes (falls, twisting movement), diagnoses (fracture, dislocation, soft tissue injury), scene (place of recreation or sports) identified 7,159 new claims for the period of July 2014 to June 2015 with a financial cost that was in excess of NZD \$60M (ACC, 2016). Based on the extent of cost and personal suffering associated with injury, the identification of people who are at risk of a non-contact sporting or recreational injury would be very beneficial.

Fortunately, YBT can be administered quickly and reliably in most settings and could contribute to identifying those with an elevated level of risk for lower extremity injury (Lehr et al., 2013). Indeed, the reach directions of YBT have been shown in a group of high school basketball players to be predictive of non-contact lower extremity injury (Plisky et al., 2006). Participants with a greater than 4 cm anterior right-to-left reach distance discrepancy were more than twice as likely (OR = 2.5, 95% CI = 1.4, 5.3) to sustain a noncontact lower extremity injury than those less than 4cm. Moreover, girls with less than 94% of composite reach distance of their leg length were 6.5 times more likely to sustain (95% CI = 2.4, 17.5) a noncontact lower extremity injury during the basketball season than ($P < 0.05$) (Plisky et al., 2006).

A recently published study by Smith, Chimera and Warren (2015) on 184 NCAA Division 1 collegiate athletes from multiple sports aimed to determine the association between YBT scores (asymmetry and composite) and noncontact injuries sustained over the competitive season. Smith, Chimera and Warren (2015) found that a greater than 4 cm asymmetry (sensitivity, 59%; specificity, 72%) in the anterior direction was significantly associated with noncontact injury (OR = 2.33; 95% CI = 1.15–4.76) (Smith, Chimera, & Warren, 2015). However, contrary to the findings of Plisky et al (2006), Smith et al (2015) did not find the composite score to be predictive of injury in this athletic population (Smith et al., 2015).

Some classical ballet positions rely on hip external rotation to achieve a large turnout angle. It has been observed that “Ballet dancers often attempt to increase turnout angle through excessive motions at the foot or knee that may be associated with the development of musculoskeletal pathology.” (Gilbert, Gross, & Klug, 1998). A research project by Filipa, Smith, Paterno, Ford, and Hewett (2013) investigated the predictive relationship between SEBT (YBT reach directions only), and functional turnout angle in a group of 10 pre-pubescent (ages 5 to 9) female ballet dancers found composite reach performance of SEBT on the dominant limb was a significant predictor of functional turnout angle ($r^2 = 0.49$, $P = 0.02$), and on the non-dominant limb demonstrated a trend toward prediction of functional turnout angle ($r^2 = 0.35$, $P = 0.07$) (Filipa et al., 2013). Based on these findings Filipa et al (2013) suggested that pre-pubescent dancers who present with decreased functional turnout angle should be considered for SEBT screening to identify dancers that might be at increased risk for lower extremity injury (Filipa et al., 2013).

7.11 REHABILITATION IN RESPONSE TO IDENTIFYING YBT DEFICITS FOR INJURY PREVENTION PURPOSES

In addition to the previously mentioned rehabilitative efforts, improving dynamic postural control has been a fundamental objective in both injury rehabilitation and injury prevention programs as well, due to poor postural control being associated with injury in numerous populations (DiStefano, Clark, & Padua, 2009). Several studies have used SEBT as an outcome measure for dynamic postural control in training / prevention programs aimed at preventing falls in middle-aged women, increasing dynamic balance in healthy adults and to prevent ankle sprain injuries (Bouillon, Sklenka, & Driver, 2009; Kahle & Gribble, 2009; Leavey, Sandrey, & Dahmer, 2010). An investigation into the effects of a 6 week long core stability training protocol on dynamic balance found a significant increase in SEBT's antero-medial and medial reach directions (with a 4% and 6 % increase respectively) over the 6 weeks period when compared to the non-exercising control group (Gribble et al., 2012; Kahle & Gribble, 2009). An additional example of the use of SEBT as an outcome measure is the study by Bouillon et al. (2009) who compared two different training protocols implemented on cycle ergometers by middle-aged women. Bouillon et al. (2009) found that the Women in the exercise groups (Strength ergometer: $n = 7$, age 51.0 ± 4.85 years, Standard ergometer: $n = 10$, age 49.8 ± 2.19 years) meaningfully improved their reach distances in the posterior, posterolateral, posteromedial, and lateral directions of SEBT when compared to the control group (Control: $n = 7$, age 46.4 ± 3.6 years) (Bouillon et al., 2009). An additional example of SEBT as an outcome measure is the 6 week study conducted by Leavey et al (2010) examining the effects of proprioceptive training or proprioceptive training in combination with gluteus medius strengthening exercises, on 48 healthy male and female college students using SEBT as the main outcome measure. These researchers found that both, proprioceptive training exercises ($0.99 \pm 2.19\text{cm}$ to $5.65 \pm 3.91\text{cm}$) as well as proprioception training combined with gluteus medius strengthening exercises ($1.53 \pm 2.14\text{cm}$ to $7.62 \pm 7.96\text{cm}$) were able to improve SEBT reach distances when compared to the control group who did not perform either the proprioceptive training, or gluteus medius strengthening exercises (Leavey et al., 2010). However, SEBT reach distances improved the most in the group that combined the proprioceptive and gluteus medius strengthening modalities for 4 of the 8 reach distances of anterior, medial, posteromedial, and posterior directions ($2.85 \pm 6.2\text{cm}$ to $6.26 \pm 3.19\text{cm}$) (Leavey et al., 2010).

7.12 THE CLINICAL IMPLICATION OF IMPROVING SEBT REACH DISTANCES

The clinical implication of these findings is that the selected exercise types or interventions chosen by the researchers were able to improve SEBT reach distances in healthy participants. Therefore, those participants prescribed intervention programs improved their functional reach distances and these improvements were detected by the YBT. This could potentially enable clinicians to screen individuals for YBT reach deficit in relation to their leg length, or reach asymmetry, prior to undertaking a new physical activity modality or when going from a sedentary to an active lifestyle. Doing so could enable practitioners to modify the activity prescription of those with a meaningful reach deficit and prescribe them an appropriate intervention program to increase their functional reach, and subsequently, measure these improvements compared to the previously established YBT scores.

Additionally, a research project conducted by Myer et al (2005) investigating performance outcomes alongside movement quality (assessed by 3-dimensional motion analysis and several athletic performance indicator tests) in 41 female athletes (age, 15.3 ± 0.9 years; weight, 64.8 ± 9.96 kg; height, 171.2 ± 7.21 cm) found simultaneous benefits in both outcomes (Myer, Ford, Palumbo, & Hewett, 2005). In this research, Myer et al (2005) recruited female athletes from various background for 6 weeks of training that included several components of neuromuscular training such as plyometric, core strengthening and balance, resistance training, and speed training in order to measure the performance and lower-extremity movement quality outcomes in female athletes (Myer et al., 2005). In addition to performance enhancement benefits of increased strength, vertical leap, single-leg hop distance, and vertical jump, they also found that the training group decreased knee valgus torque by 28% (60.4 ± 5.5 Nm to 43.4 ± 3.3 Nm; $p < 0.001$) and varus torques by 38% (34.0 ± 2.8 N-m to 21.1 ± 1.7 N-m; $p < 0.001$) while the untrained control subjects demonstrated no change (Myer et al., 2005). Reducing knee valgus torques is important in preventing ACL injuries since athletes, especially females, with increased dynamic valgus are at increased risk of ACL injuries (Hewett et al., 2005). Based on these outcomes Myer et al (2005) concluded that female athletes prescribed a complete training program aimed at injury prevention alongside performance enhancements can improve on both these aspects and gain significant benefits in performance as well as movement quality (Myer et al., 2005).

7.13 THE YBT'S ASSOCIATION WITH ALTERNATIVE MOVEMENT SCREENING PROTOCOLS

A better understanding of the association between different movement screens offers several advantages for the practitioner. For example, if there is a high correlation between tests it might be possible to use only one of them to screen athletes. However, if there is a certain amount of doubt or borderline test performance, other tests could be implemented to assist with interpretation of initial findings. Additionally, if a test captures the same information that another test does, but also captures additional clinically useful information about the person, in some instances that test could be the preferred test of choice.

7.14 STUDIES INVESTIGATION THE ASSOCIATION BETWEEN YBT AND OTHER MOVEMENT SCREENS

Available data quantifying any existing association between the YBT and a similar movement screen protocol is relatively scarce with only three results found during a search of electronic bibliographic databases. The three studies investigated relationships between YBT and other movement screening tests (Beaulieu, 2012; Morrell, 2012; Reyland, 2016). A research thesis by Morrell (2012) investigating the injury predictive capabilities of both SEBT and the composite Functional Movement Screen (FMS) scores in Division 1 college American football players, found SEBT anterior reach score being statistically significant in its predictive role (Mean $67.97 \pm 7.25\%$, CI 95% = 0.05 – 0.81, $P = 0.035$) (Morrell, 2012). Additionally, Morrell (2012) also stated that odds ratios derived from the cut-off scores indicated that SEBT anterior reach (OR = 4.63) was a better predictor of lower extremity injuries than the FMS scores (OR = 2.08) (Morrell, 2012). Based on these findings Morrell (2012) suggested that SEBT anterior reach would be a useful pre-season screening tool for lower extremity injury in American football athletes (Morrell, 2012). However, a limitation of this study described by Morrell was that certain athletes participating in the study were required to wear taping or bracing during practice and competition depending on their injury history. This might have biased the study outcome in two possible ways. Firstly, previous research has shown that players who were previously injured are at greater risk for injury in the following season when compared to previously un-injured players (Hazard Ratio 2.7; 95% CI 1.7 to 4.3, $p < 0.0001$) (Hägglund, Waldén, & Ekstrand, 2006). Indeed, a literature review by Murphy, Connolly and Beynnon (2003) states that there is strong evidence for a

previous injury as an intrinsic risk factor for re-injury and places an athlete at increased risk of suffering an injury (Murphy, Connolly, & Beynnon, 2003). Secondly, a review of the literature by Murphy et al (2003) identified that there is general agreement within the scientific literature for ankle joint bracing or taping decreasing the incidence of ankle joint injuries possibly by increasing the kinesthetic awareness of ankle positioning and support to the ankle joint by limiting hindfoot motion, particularly inversion (Murphy et al., 2003). Therefore, the taping or bracing methods applied to support previously injured joints may reduce rates of both injury and re-injury rates, thus impacting the outcome and interpretation of the FMS and SEBT as a pre-participation test for injury prediction.

Contrary to the findings of Morrell (2012), Beaulieu's (2012) research found a moderate association between SEBT and FMS composite scores ($r = 0.478$, $p = 0.031$) in a population of healthy football players (Beaulieu, 2012). Finally, a recently published research thesis investigating the concurrent validity between FMS, YBT and Landing error scoring system involving professional rugby players found that FMS (not taking clearing test into account) displayed a 'moderate' correlation with the YBT (Reyland, 2016).

7.15 THE CLINICAL IMPLICATIONS OF THESE FINDINGS BETWEEN YBT AND OTHER MOVEMENT SCREENS

Based on three unpublished theses (Beaulieu, 2012; Morrell, 2012; Reyland, 2016) the strength of correlation between SEBT and FMS appears to be moderate. This may indicate that SEBT and FMS assess different aspects of 'movement quality'. Based on the moderate correlation, it is not recommended to use these test interchangeably. Indeed, implementing them alongside each other to capture a wider range of clinically important information, or perhaps alongside other movement screens previously found to be predictive of injuries in certain populations might be more sensible depending on the clinician's need at the time.

8 THE SITTING-RAISING-TEST

8.1 A SHORT OVERVIEW OF SRT

Sitting and rising from the floor is a basic functional task required for quality of life and independence (De Brito et al., 2012; VanSant, 1988). Scientific literature investigating the SRT is scarce in the English-language literature. The SRT provides a measure of a person's capacity to move from standing to a seated position on the floor and then return to standing. Test administration only requires a 2m x 2m, non-slippery surface and a simple low profile mat (a precautionary safety feature), and can be administered in a few minutes, thus making it a low cost, field expedient option for the assessment of musculoskeletal health in most settings. Similarly to the YBT, successful performance in SRT requires a certain level of strength, flexibility, mobility and dynamic balance, to assess the participant's musculoskeletal fitness. In addition to assessing these components of musculoskeletal fitness, the SRT has also been used as a measure of association between musculoskeletal health and life expectancy in older adults (De Brito et al., 2012).

While direct specific research on SRT performance is still in its early stages the fundamental skill of moving from a seated position to a solid bilateral stance remains an important part of physical independence, and everyday life (VanSant, 1988). Recreational, as well as everyday activities such as gardening, exercise, housework require people from all age groups to perform this seemingly simple, but functional task on a daily basis (Kelley, Aaron, Hynds, Machado, & Wolff, 2014). The importance of retaining the ability to perform this fundamental task is highlighted in aging people. As people age it becomes progressively difficult to gain a standing stance. Indeed, healthy elderly adults can take twice as long to gain this position when compared to younger people (Bloch, 2012).

8.2 THE DEVELOPMENT AND RELIABILITY OF SRT

The SRT was developed and implemented in clinical settings by Brazilian-born Claudio Gil Soares de Araújo in the late 1990s in an effort to further improve previous health-related physical fitness tests such as the ‘Get-up and Go’ or its variations. The development of the SRT was undertaken to eliminate equipment or space requirements and objectively quantify performance by deducting points for each support (i.e. hand or knee) used during the test (De Brito et al., 2012). The limited number of studies published in English using SRT has stated that SRT scoring is reliable, and has been applied in a variety of research contexts in the past (De Brito et al., 2012).

8.3 SRT ASSOCIATION WITH ALL-CAUSE MORTALITY

A study looking at the SRT as predictor of all-cause mortality followed over 2000 adults for 6.3 years (median value), with an age range that spanned from 51 to 80 years old found that those who needed more than one hand or knee to assist in sitting down or getting up from the floor exhibited five to six times higher risk of all-cause mortality in either gender when compared to their reference group ($p < 0.001$) (De Brito et al., 2012). Furthermore, each point increment in the SRT score was associated with a 21% reduction in all-cause mortality (De Brito et al., 2012). In addition, a clinically based retrospective study evaluating 3900 participants Flexi test score in relation to their SRT performance found the SRT and Flexi test scores to be moderately associate ($P < 0.001$) in people aged between 6 to 92 years old (Brito, de Araújo, & de Araújo, 2013). In this study, the authors concluded that the actions of sitting and rising from the floor are partially dependent on flexibility, regardless of sex, and across a wide range of age groups (Brito et al., 2013).

8.4 DETERMINANTS OF ABILITY TO STAND FROM THE FLOOR

Other known variables that impact on a person’s ability to stand up from the floor or a deep squat position (eg typical chair of 30 cm height) are underlined by studies such as Naugle, Higgins, and Manini (2012) who investigated functional impairments of individuals with obesity. Naugle et al (2012) found that a person’s capacity to gain a standing stance from a low chair of 30 cm height, kneeling or supine position has been significantly affected by body mass, placing obese individuals at a higher risk of disability rating when compared to their

peers with lower body mass (Naugle et al, 2012). Bohannon and Lusardi (2004) found that lower extremity strength was an important determinant in rising from the floor in a group of healthy older adults (Bohannon & Lusardi, 2004). Furthermore, research looking at ‘rising from the floor test’ a test that shares some similarities with SRT has demonstrated acceptable concurrent validity with joint mobility, balance, gait velocity and physical activity levels (Klima et al., 2015).

9 SUMMARY OF MEASUREMENT PROPERTIES FOR SRT AND YBT

Both the instrumented YBT and the SRT are simple, clinically applicable, field–expedient low-cost alternatives to the more sophisticated and expensive laboratory testing instruments aimed at evaluating dynamic balance and postural control. Identifying modifiable injury risk prior to undertaking a new physical activity routine or sport could contribute to reduced injury rates thus increased physical activity. Increasing physical activity levels has powerful health benefits, and the combination of reduced injury rates and increased physical activity could aid in reducing the overall as well as injury specific healthcare costs.

Instruments for clinical application can be assessed across a number of different properties (Terwee et al., 2007). These includes the availability of normative data for a range of different populations, construct validity, inter and intra-rater reliability, floor and ceiling effect, responsiveness and interpretability (Terwee et al., 2007). Table 3 shows a summary of measurement properties identified for the SRT and instrumented YBT.

TABLE 3: Measurement properties of the instrumented YBT and SRT.

	Instrumented YBT	SRT
Normative data ¹	Hudson, Garrison, and Pollard (2016) (Female collegiate volleyball players.) Teyhen et al. (2014) (Military population.) Breen, Howell, Stracciolini, Dawkins, and Meehan (2016) (Athletes between the ages of 10 and 18 years old.) Butler, Southers, Gorman, Kiesel, and Plisky (2012) (Male high school, collegiate, and adult professional soccer players.)	NSI ⁸ (Unpublished data is available from the author.) Published data for (Ages 51 – 80) De Brito et al. (2012)
Construct validity ²	NSI	NSI
Inter-rater reliability ³	(Shaffer et al., 2013) (Plisky et al., 2009) (Faigenbaum et al., 2014)	NSI
Intra-rater reliability ⁴	(Plisky et al., 2009)	NSI
Responsiveness ⁵	Hale et al. (2007) (SEBT detected changes in the posteromedial and posterolateral directions.) McKeon et al. (2008)	NSI
Floor and ceiling effects ⁶	NSI (For healthy, active population.)	NSI (Not yet known in young, healthy, active population.)
Interpretability ⁷	Yes. Impaired movement quality.	Yes. Reduced quality of life.
<ol style="list-style-type: none"> Normative data – refers to “data that characterizes what is usual in a defined population at a specific point or period of time” (O'Connor, 1989). Construct validity – “Construct validity refers to the extent to which scores on a particular instrument relate to other measures in a manner that is consistent with theoretically derived hypotheses concerning the concepts that are being measured.” (Terwee et al., 2007). Inter-rater reliability – refers to “how interchangeable are the ratings from multiple raters in assessing the results of a randomized clinical trial” (Kraemer, 2014). Intra-rater reliability – refers to the ability of a rater or a measurement system to reproduce quantitative or qualitative outcomes under the same experimental conditions (Gwet, 2007). Responsiveness - Responsiveness has been defined as the ability of an instrument to detect clinically important changes over time, even if these changes are small (Terwee et al., 2007). Floor or ceiling effects - Floor or ceiling effects are considered to be present if more than 15% of respondents achieved the lowest or highest possible score, respectively (Terwee et al., 2007). Interpretability - Interpretability is defined as the degree to which one can assign qualitative meaning to quantitative scores (Terwee et al., 2007). NSI – No study identified 		

10 COMPARISON AND CONTRAST OF PERFORMANCE DETERMINANTS BETWEEN SRT AND YBT

This section of the Literature Review aims to reason for the similar physical requirements shared between the YBT and SRT. There is no previous research that directly compares these two movement quality tests, regardless, it is evident that YBT and SRT share some common performance determinants. For example, comparisons can be reasoned for balance (Bohannon & Lusardi, 2004; Gribble et al., 2012; Kinzey & Armstrong, 1998) lower extremity strength (Bohannon & Lusardi, 2004; Leavey et al., 2010) and flexibility (Brito et al., 2013; Overmoyer & Reiser, 2015). The key determinants for each test are shown in Table 4.

TABLE 4: A collection of similarities and differences within YBT and SRT performance determinants.

	YBT	SRT	Rationale
Balance	Higher	Lower	Single limb support requires the performer to maintain their center of mass over a small, fixed base of support (Bohannon & Lusardi, 2004). SRT is a bilateral movement, while YBT is a single limb movement. Thus, the YBT reduces (the number of) points of contact thus support available by 50% when compared to SRT.
Posture control strategy	Both required <i>Ankle</i> strategy > hip strategy	Both required <i>Hip</i> strategy > ankle strategy	The posture control system has at least two distinct modes of operation, namely the ankle strategy and the hip strategy to restore the body balance in the sagittal plane (Fujisawa et al., 2005). On a flat surface, when the inclination of the body segments is small, the standing posture is controlled with the ankle strategy (Fujisawa et al., 2005) Thus, SRT's significantly larger hip joint angle (Therefore large inclination of the upper body segment.) in the deep squat position (when compared to YBT), suggests that SRT would rely more on hip strategy during this portion of the movement. Muscle recruitment sequence differs between these two strategies, in a way that hip strategy more likely to recruit lower-extremity muscles in a proximal to distal sequence while ankle strategy is the opposite and more likely to follow a distal to proximal order.
Lower-extremity strength	Required (Potentially <i>lower</i> quadriceps activity.)	Required (Potentially <i>higher</i> quadriceps activity.)	“Hip extensor and knee flexor strength were positively correlated with YBT anterior distance. Hip extensor, hip abductor, and knee flexor strength were positively correlated with the YBT posteromedial distance. Hip extensor and knee flexor strength were positively correlated with YBT posterolateral distance” in adult females (D.-K. Lee, Kim, Ha, & Oh, 2014). Additionally, EMG analysis of lower extremity muscle recruitment patterns during an unloaded squat suggests that a deep squat portion, acute knee joint angle (just like during the deep portions of SRT) requires higher quadriceps activity than one would require during a YBT test (not so acute knee joint angle 0-30 degrees (Isear Jr, Erickson, & Worrell, 1997). Thus, while both movements appear to really on the strength of the lower extremity, the distribution of work required by each muscle group to be performed might be significantly different due to the significantly different joint angles produced during the performance of these two tests.
Core stability and strength	Required	Required	Core stability can be described as the ability to maintain a neutral spinal alignment, optimal trunk position, and the transfer of loads along the kinetic chain (Bliven & Anderson, 2013). Both tests require the participant's ability to maintain a close to optimal trunk position throughout. For example, allowing a critical amount of displacement of trunk position from the equilibrium needed to maintain balance would result in a loss of control over the movement (The loss of balance.).
Lower-extremity flexibility.	Required	Required	Actions needed to perform SRT are partially dependent on flexibility (Brito et al., 2013). Adequate levels of hip flexion and external rotation are needed to achieve a deep squat position necessary to perform the SRT. Ankle dorsiflexion and hip flexion measures contribute to the overall Y-Test scores (Overmoyer & Reiser, 2015), thus a flexibility limitation in these joints could negatively influence the YBT performance.

11 RATIONALE FOR THIS THESIS

Table 3 highlights the numerous gaps in the scientific literature concerning the YBT and SRT. Establishing knowledge of normative data is useful to provide appropriate comparisons, although to date there have been no studies reporting this for SRT or YBT. In relation to construct validity, improved knowledge of the correlation between the YBT and SRT could be beneficial to practitioners for several reasons. Firstly, if a high correlation is found then it could be that the tests are interchangeable, enabling practitioners to select the test that suits the particular situation or resources available. Secondly, if the correlation is low, this battery of tests is probably measuring differing aspects of movement qualities and perhaps highlights a need for future research efforts. Additionally, floor and ceiling effects are considered to be present when at least 15% of participants achieve the lowest or highest possible score, respectively (Terwee et al., 2007). In the context of movement quality screening this could potentially imply that the screening test is either too challenging for a particular population (too many people fail the test, possibility of too many false positives) or too easy (too many passes it with top scores, possibility of too many false negatives), and thus not an appropriate choice of movement screening test for that particular population. The presence of floor or ceiling effects limits content validity, reliability, and responsiveness of the test (Terwee et al., 2007). Given these gaps in the present literature, the Aim of the study reported in Section 2 of this thesis was to establish normative data, floor and ceiling effect, and construct validity in both of these tests for young, healthy, active adult population.

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Section 2: Manuscript

**An investigation of the relationship between the Y-Balance Test
and the Sit-to-Raise-Test in a sample of active healthy adults.**

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ABSTRACT

Background: Both the Y-balance test (YBT) and Sit-To-Raise test (SRT) appear to share similar requirements in terms of physical attributes needed for test performance. Nonetheless, to date, there are no studies comparing performance between these two movement tests.

Objectives: To determine the strength of association between SRT and YBT scores, as well as report participant performance characteristics for each test.

Setting: Field-based data collection.

Participants: A convenience sample of 100 healthy adults (n=69 males, mean \pm SD age was 29.8 ± 11.1 years, body weight 86.3 ± 12.0 kg, and height 177.4 ± 7.4 cm; n=31 females, age 29.8 ± 8.9 years, body weight 64.1 ± 9.3 kg, and height 166.5 ± 6.5 cm) were recruited from a recreation centre and other campus facilities.

Main outcome measures: SRT and normalised YBT scores were administered using standardised test protocols and scoring criteria.

Results: Right and left anterior YBT reach direction and total SRT scores were moderately correlated for the right ($r = 0.469$) and left ($r = 0.352$) anterior reach directions. Additionally, all other individual, as well as composite reach directions of the YBT displayed a small correlation with the SRT ($r = 0.202$ to 0.352). The sitting component of the SRT had a small negative correlation ($r = -0.160$, $p = 0.111$) with height, and age ($r = -0.259$, $p = 0.009$), but no clear correlation was found between the participant's height ($r = 0.023$, $p = 0.821$), height to leg-length ratio ($r = -0.079$, $p = 0.433$) and SRT sitting component performance ($r = -0.079$, $p = 0.433$). The SRT raising component had a small negative correlation with body weight ($r = -0.267$, $p = 0.007$), and age ($r = -0.174$, $p = 0.083$) but no clear correlation with participant's height ($r = -0.135$, $p = 0.179$), or height to leg length ratio ($r = -0.096$, $p = 0.345$).

Conclusions: The small to moderate correlation between total SRT scores and all YBT reach directions indicates each test addresses a similar underlying construct.

Keywords: movement screening, y-balance test, sitting-raising test, sit-to-raise test

INTRODUCTION

Physical activity is well known to be beneficial for the prevention of age-related disease development (Reiner, Niermann, Jekauc, & Woll, 2013). Further, physical activity is important in populations with existing chronic health conditions (Schoenborn & Stommel, 2011). The American College of Sports Medicine (ACSM) recommends that adults between the ages of 18 to 65 should maintain a physically active lifestyle to promote and maintain good health (Carlson, Fulton, Schoenborn, & Loustalot, 2010), however, participation in physical activity is also associated with risk of injury (Hootman et al., 2001). The risk of activity-related injury rises for people who participate in sporting activities, are runners, engage in more than 75 minutes of physical activity per week, or who have a moderate to high level of cardiorespiratory fitness (Hootman et al., 2001). Injury aetiology can be described in terms of intrinsic and extrinsic risk factors that may predispose an individual to a sporting injury (Meeuwisse, Tyreman, Hagel, & Emery, 2007). Examining these modifiable, predisposing factors during a pre-participation screen could potentially reduce injuries associated with the ongoing participation of a physically active lifestyle (Meeuwisse et al., 2007).

The Y-Balance test (YBT) and Sitting-Raising test (SRT) are both attractive field expedient assessments that could be easily implemented for pre-participation evaluation (PPE) purposes. The YBT and SRT tests originate in two distinctly different populations with the YBT often implemented as a screening or rehabilitative outcome measure for competitive and recreational athletes, while the SRT originates from a general health perspective particularly in older adults. To some extent, it appears that the YBT and SRT share similar requirements in terms of physical qualities that are needed to perform them to an adequate level (balance, joint mobility, lower extremity and core strength). However, to date, no studies have compared performance between these two movement tests. Further, there is little available reference information available that describes reference ranges of adults on the SRT. Therefore, the aims of this study were (1) to determine the strength of association between SRT and YBT scores, (2) to determine the strength of association between participant characteristics (age, weight, height, gender, activity level, self-reported physical health), SRT, and YBT scores; and (3) to generate preliminary reference data, including floor and ceiling effect, and convergent validity for both of these tests in a healthy, active adult population.

METHODS

STUDY DESIGN

This study employed a cross-sectional correlation design. A convenience sample of active healthy adults were recruited from a public sport and recreation centre. All participants gave written informed consent. This study was approved by the Unitec Research Ethics Committee (UREC 2015-1036).

PARTICIPANTS

Volunteers were eligible for participation if they satisfied the following criteria: The only inclusion criterion was: (1) aged 18 and over. Exclusion criteria were: (1) no history of previous vestibular disorders or other disorders known to impair balance, (2) no history of lower extremity injury that required medical attention in the past 6 weeks, (3) no history of acute low back pain in the past 6 weeks, (4) absence of musculoskeletal abnormalities that would prevent or interfere with the execution of either test, (5) having not consume more than one standard serving of alcoholic beverage in the last eight hours, or any alcoholic beverage in the last four hours prior to the measurements, (6) not taken any medication that may alter balance or could cause drowsiness, and (7) able to walk without assistance. A target sample of 100 eligible participants was planned, this number representing the estimated maximal achievable sample over a 6-week data collection period and within the resources available for a thesis.

VARIABLES

SHORT FORM 12-ITEM HEALTH STATUS SURVEY

The SF-12v2 is a 12 item questionnaire designed to evaluate physical and mental health and can be completed in as little as 2 minutes (Cheak-Zamora, Wyrwich, & McBride, 2009). It has shown acceptable reliability and validity over a one-week recall period (Maurish, 2012). Additionally, the SF-12v2 has high internal consistency, the Physical Component Scores

(PCS) showed high test–retest reliability (ICC = 0.78), and the Mental Component Scores (MCS) demonstrated moderate reliability (ICC = 0.60) (Cheak-Zamora et al., 2009). Furthermore, PCS and MCS have acceptable convergent validity when compared to other health status measures (except when compared to EuroQOL, showing poor to adequate correlation between PCS and EuroQOL’s self-care section ($r = 0.32$) (Cheak-Zamora et al., 2009).

THE INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

The International Physical Activity Questionnaire (IPAQ) is a self-reported measure of physical activity and was developed to estimate physical activity across different countries and socio-cultural settings (Boon, Hamlin, Steel, & Ross, 2008). A study conducted on the reliability of the IPAQ in 12 countries showed the IPAQ long form’s pooled data achieving good reliability ratings with an ICC range of 0.79 – 0.82 (95% CI) (Craig et al., 2003). Additionally, research looking at the IPAQ long form demonstrated acceptable levels of validity for total physical activity ($r = 0.30$ to 0.32) but stated that when self-reported data was compared with data from the accelerometer, self-reported levels of moderate, vigorous and total physical activity were overestimated (Boon et al., 2008). In contrast, a doubly-labelled-water method validation study found the IPAQ long form was biased toward *underestimating* physical activity-related energy expenditure at higher levels of physical activity (Maddison et al., 2007). Regardless of the outcome, both studies were in general support of the IPAQ long form as a questionnaire with satisfactory levels of validity for measurement of self-reported physical activity (Boon et al., 2008; Maddison et al., 2007).

DATA COLLECTION PROCEDURES

Data collection for both questionnaires and movement tests occurred over a single 30-minute session. Data collection procedures began by recording the participant’s physical characteristics (gender, age, height, weight, and leg length). Following the collection of physical characteristics, participants were required to complete the SF-12v2 to assess self-reported health status, and the IPAQ to assess physical activity levels over the last 7 days. Finally, the Y Balance Test (YBT) movement screen and Sitting-Raising-Test (SRT) were administered.

YBT PROTOCOL

An instrumented YBT kit (Functional Movement Screen Systems, Virginia, USA) was used to measure the anterior, posteromedial and posterolateral reach directions and was administered based on the standardised protocol described by Plisky (Plisky et al., 2009). Prior to YBT measurements, lower limb length for both left and right lower limbs were measured for use in subsequent normalisation of reach measures and to help to derive a composite score (Plisky et al., 2009). Prior to leg length measurement participants were required to “elevate and move their hips up and down a few times then place it back on the ground”. Following this, the researcher passively straightened the legs and measured the leg length with a cloth measuring tape from the anterior iliac spine to the most lateral portion of the malleolus on the ipsilateral side, on both left and right sides of the participant. Participants observed the researcher demonstrate YBT performance and were encouraged to perform several practice trials to minimise the impact of potential learning effects identified by (Hertel, Miller, & Denegar, 2000). All participants were asked to perform the test in bare feet. After three successful reach distances were recorded the participants changed to the contralateral stance and repeated the procedure until three successful reach distances were achieved. The order of reach directions performed was as follows: right anterior, left anterior, right posteromedial, left posteromedial, right posterolateral and left posterolateral which is consistent with the standard testing order developed by the developer of the YBT kit (Plisky et al., 2009). Scores were derived as recommended by Plisky et al (2009): From each reach direction, the longest reach distance achieved by the participant out of three successful trials was selected as the reach distance that contributed towards the composite reach distance. The relative (normalised) reach distance (percentage of leg length) was calculated by dividing absolute (best) reach distance by limb length, then multiplying by 100. The composite reach distance was calculated as the sum of the three best reach distances (best of each direction) divided by three times leg length, then multiplied by 100. To reduce the effect of fatigue, participants were encouraged not to rush and to “take their time.” between each trial. Only trials that were ‘successful’ were recorded, therefore, attempts where the participant failed to maintain single leg stance, failed to maintain reach foot contact with the reach indicator’s target area, attempted to use the reach indicator as a base of support, or failed to return the reach foot to the starting position under control (Plisky et al., 2009) were discarded.

SRT PROTOCOL

The SRT was first described in the English language literature by De Brito et al (2012) as a test that assesses musculoskeletal fitness and life expectancy in older adults through the evaluation of the subject's ability to take a seated position on the floor and then rise from it (De Brito et al., 2012). Prior to commencing the three SRT trials participants were shown an A5 sized picture, printed on an A4 sized laminated card with a picture sequence representing an SRT performance that would earn full scores for both actions of the SRT test (sitting as well as the raising component) (Figure 1).

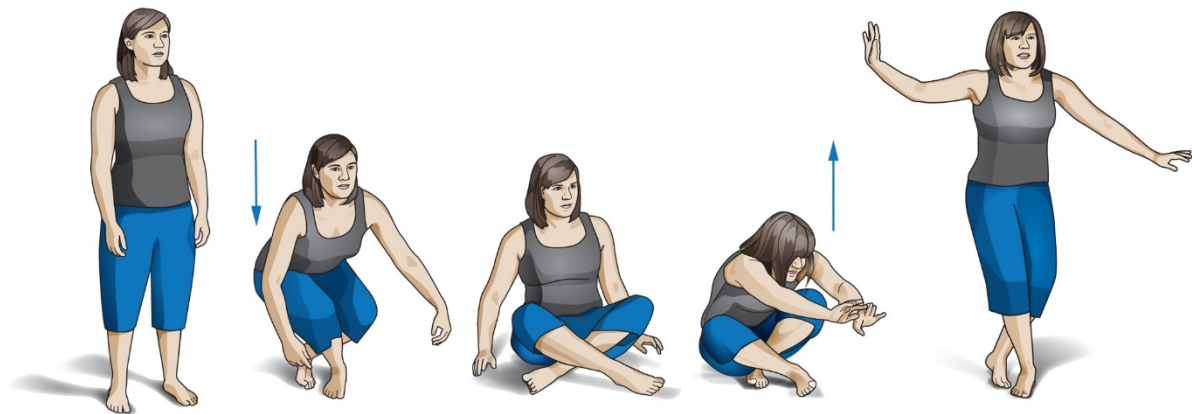


FIGURE 1: SIT TO RAISE TEST. PICTURE REPRODUCED WITH PERMISSION FROM THE ARTIST ROEN KELLY (WILSON, 2014).

In addition to the visual cues provided, verbal instructions of “Perform the movement at your own speed with the least amount of support you think is needed.” were also provided. Additional verbal cues were also provided between attempts if the researcher observed that the participant might be able to improve their SRT score by potentially reducing support utilised or maintained their balance better. It was then up to the participant's discretion to either implement these pointers or ignore them (e.g. they felt they could not reduce the additional support utilised any further and needed a hand or knee to be able to perform the movement). Participants were required to perform the movement without any footwear, on a non-slippery carpet tiled surface. In accordance with the work of De Brito et al (2012), SRT scores of 5 points were allocated for both the sitting and raising part performed without any additional support for a possible total of 10 points.

Each component of the SRT test (sitting and raising components) was scored from a total of 5 points if performed with no loss of balance or additional support. However, half a point (0.5) was deducted for partial loss of balance during any time of the performance of the test, and a one-point deduction was applied when the participant placed any of his/her hand, forearm, knee or side of the leg on the floor in order to take the seated position, or to raise from it. There was also a one-point deduction if the participant placed a hand on their knee in order to assist them in either the sitting or raising part of the test. For safety reasons a small profile high-density foam matt of 2.5 cm thickness was placed behind the participants for the duration of SRT performance.

STATISTICAL ANALYSES

Raw scores were extracted from data collection sheets, tabulated in spreadsheets and checked for errors before importing into statistical software (IBM SPSS v22, IBM, Armonk, NY). Descriptive statistics were generated for all measures (IPAQ, SF-12v2, YBT, and SRT). To investigate the correlation between measures Pearson's correlation coefficient (r) was calculated for each pair-wise relationship. Differences between group means were calculated using independent t-test. Descriptors for the magnitude of correlation were based on Hopkins' scale of magnitudes (Hopkins, 2000).

RESULTS

One hundred healthy, active adults met the inclusion criteria and were enrolled in the study. For male participants ($n=69$), the mean \pm SD age was 29.8 ± 11.1 years, body weight 86.3 ± 12.0 kg, and height 177.4 ± 7.4 cm. For female participants ($n=31$) the mean age was 29.8 ± 8.9 years, body weight 64.1 ± 9.3 kg, and height 166.5 ± 6.5 cm. Descriptive statistics for physical activity and health status are displayed in Table 1.

TABLE 1: DESCRIPTIVE PARTICIPANT CHARACTERISTICS FOR PHYSICAL ACTIVITY AND HEALTH STATUS BASED ON SELF-REPORT MEASURES.

		Physical Activity (IPAQ scores)					Health-Related Quality of Life (SF12v2)			
		Sitting	Walking	Moderate	Vigorous	Overall		PCS	MCS	SF6D-R2
Males n=69	Median	1,965	1,101	1,440	2,040	3.0	Mean	54.1	50.3	0.76
	(IQR)	(1552)	(2397)	(3690)	(3060)	(0.75)	(SD)	(6.8)	(7.8)	(0.11)
	Min	540	0	0	0	1.0	Min	25.3	28.1	0.41
	Max	5,700	12,029	11,610	3,160	3.0	Max	69.6	63.3	1.0
Females n=31	Median	2,280	924	1,380	1,960	3.0	Mean	57.1	46.3	0.73
	(IQR)	(1920)	(2244)	(3360)	(3,360)	(1.0)	(SD)	(5.5)	(8.6)	(0.10)
	Min	660	0	0	0	1.0	Min	37.2	28.9	0.6
	Max	5,280	8,910	12,705	2,160	3.0	Max	63.8	61.3	0.92

Notes: IPAQ = International Physical Activity Questionnaire (Craig et al., 2003), SF12v2 is the short form health-related quality of life measure (version 2). PCS = Physical component score, MCS = mental component score.

YBT RESULTS

Descriptive statistics for the normalized YBT composite and individual reach directions are displayed in Table 2. More than a quarter of the participants displayed a left-right anterior reach asymmetry greater than 4 cm. The gender specific breakdown of this asymmetry can be seen in Table 3.

Although the number of female participants in this study ($n=31$) was less than males, the proportion of males ($n=69$) demonstrating asymmetry was not significantly different to females ($p=0.629$, Fisher's exact test). When observing the overall composite averages, females demonstrated a small higher overall normalised reach distance for both left and right, when compared to males (Right: mean difference = -0.1 , 95%CI = -0.15 to -0.05 , $p < 0.001$; Left: mean difference = -0.08 , 95%CI = -0.13 to -0.03 , $p = 0.001$). The difference between the average composite reach values of females and males are displayed in Table 3.

TABLE 2: Y-BALANCE RESULTS

	Composite right	Composite left	Anterior right	Anterior left	Posterior medial right	Posterior medial left	Posterior lateral right	Posterior lateral left
Males n=69								
Mean (SD)	0.96 (0.11)	0.96 (0.11)	0.65 (0.07)	0.66 (0.07)	1.05 (0.11)	1.07 (0.11)	1.02 (0.11)	1.02 (0.11)
95% CI for mean LCL, UCL	0.93, 0.98	0.94, 0.99	0.64, 0.67	0.64, 0.68	1.02, 1.08	1.04, 1.09	0.99, 1.04	0.99, 1.04
Min, Max	0.71, 1.20	0.71, 1.22	0.47, 0.82	0.49, 0.83	0.72, 1.30	0.77, 1.26	0.78, 1.24	0.71, 1.23
Females n=31								
Mean (SD)	1.05 (0.12)	1.04 (0.11)	0.67 (0.07)	0.67 (0.07)	1.07 (0.02)	1.06, (0.09)	1.06 (0.11)	1.04 (0.10)
95% CI for mean LCL, UCL	1.00, 1.09	1.00, 1.08	0.64, 0.69	0.64, 0.69	1.03, 1.11	1.03, 1.10	1.02, 1.10	1.01, 1.08
Min, Max	0.87, 1.34	0.88, 1.30	0.50, 0.79	0.49, 0.78	0.85, 1.28	0.87, 1.23	0.84, 1.27	0.86, 1.22

Notes: LCL = Lower control limit, UCL = Upper control limit. All values are normalized to leg length.

TABLE 3 TOTAL AND SEX-SPECIFIC BREAKDOWN OF YBT ASYMMETRY

	Male	Female	Total
Asymmetry absent	49	24	73
Asymmetry present	20	7	27
Total	69	31	100

SRT RESULTS

The overall (both male and female), and gender-specific total, as well as subset SRT scores, are shown in Table 4. Overall, participants performed well in both actions of SRT (sitting, and raising), as well as achieved good total SRT scores. Seventy-five percent of the participants achieved a score of ≥ 9.5 out of the possible 10 indicating that 75% of the participants did not have to utilize additional body parts for support during the SRT performance. Indeed, no participant in this sample scored less than minimum partial scores of 4 out of 5 in either component of the SRT test thus achieved at least a minimum of 8 out of 10 for total SRT score. According to De Brito et al. (2012), those that are able to achieve a minimum score of 8 are considered to have “preserved functional independence regardless of age.” For a specific breakdown of SRT score frequency achieved by the participants, refer to figure 2.

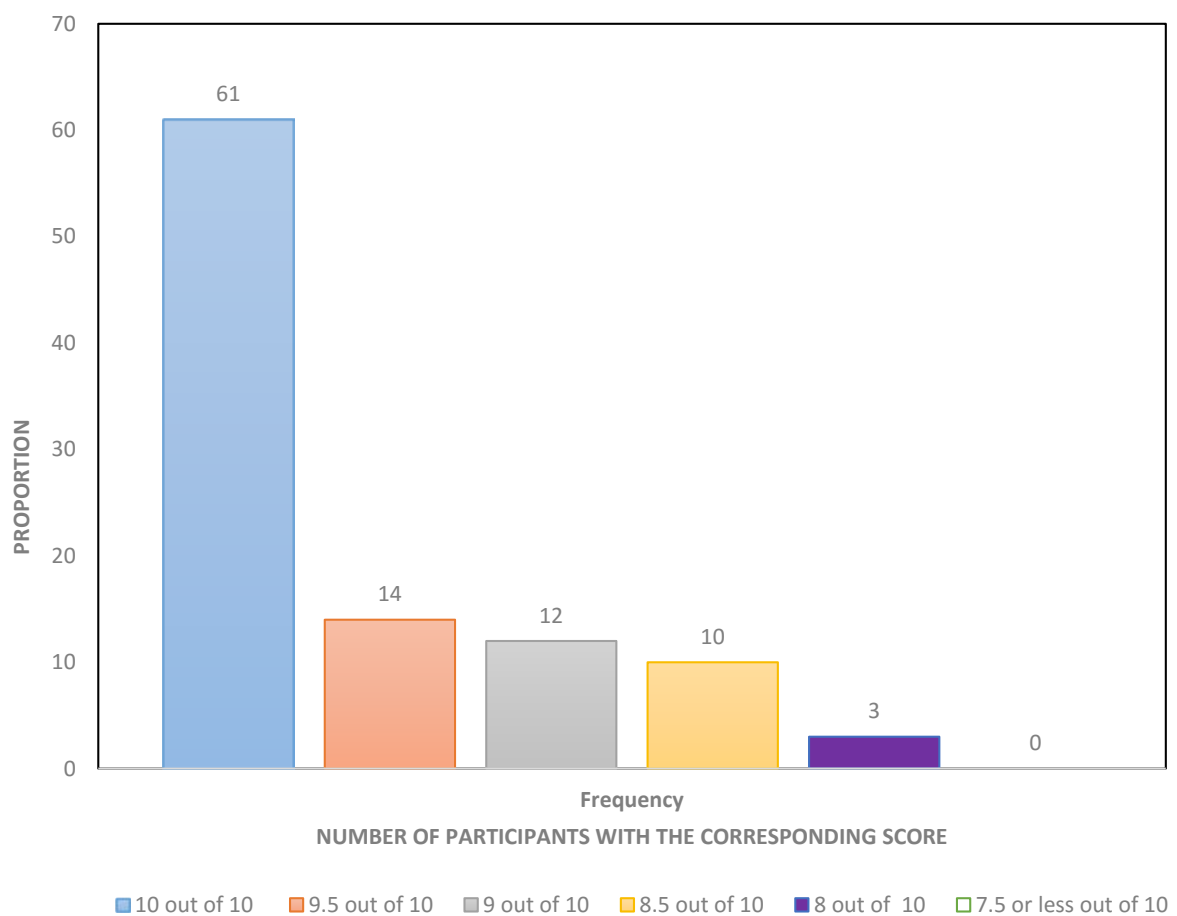


FIGURE 2: SRT SCORE FREQUENCY.

TABLE 4: OVERALL, AS WELL AS MALE AND FEMALE SPECIFIC SRT PERFORMANCE SCORES FOR EACH COMPONENT OF THE SRT, AND TOTAL SRT SCORES.

	Minimum	Maximum	Mean	Standard Deviation
Overall (n=100)				
Sitting	4	5	4.91	0.22
Standing	4	5	4.68	0.42
Total SRT score	8	10	9.60	0.58
Males (n=69)				
Sitting	4	5	4.89	0.25
Standing	4	5	4.63	0.42
Total SRT score	8	10	9.53	0.60
Females (n=31)				
Sitting	4.5	5	4.95	0.15
Standing	4	5	4.79	0.40
Total SRT score	8.5	10	9.74	0.51

There was a ‘small’ negative correlation between SRT sitting action performance and age, as well as a small negative correlation between SRT rising portion and bodyweight as indicated in Table 5. Additionally, total SRT scores also revealed a ‘small’ negative correlation with age and body weight (Table 5). This study found no statistically significant correlation between the sitting portion of SRT and bodyweight, height or leg-length height ratio. Additionally, the raising portion of the SRT showed no statistically significant relationship between age, height, and leg-length height ratio and SRT performance. Furthermore, total SRT scores did not correlate significantly with either participant’s height or leg-length torso ratio. Finally, females demonstrated higher scores than males on overall SRT scores, but this effect was ‘small’ ($p = 0.049$, Mann-Whitney U test) (Table 4). However, there was no difference when considering the sitting ($p = 0.376$) or raising ($p = 0.058$) performance.

TABLE 5: SRT'S NON GENDER SPECIFIC CORRELATION WITH AGE, HEIGHT, BODY WEIGHT AND HEIGHT-LEG LENGTH RATIO.

n=100	Pearson's correlation of SRT with			
	Age	Height	Body weight	Height - Leg length ratio
Best of sitting	r = - 0.259 p = 0.009	r = 0.023 p = 0.821	r = - 0.160 p = 0.111	r = - 0.079 p = 0.433
95% CI	-0.493 to 0.008	-0.125 to 0.176	-0.355 to 0.053	-0.291 to 0.120
Hopkins descriptor	Small	Trivial	Small	Trivial
Best of raising	r = - 0.174 p = 0.083	r = - 0.135 p = 0.179	r = - 0.267 p = 0.007	r = - 0.096 p = 0.345
95% CI	-0.377 to 0.080	-0.343 to 0.057	-0.449 to -0.043	-0.281 to 0.117
Hopkins descriptor	Small	Small	Small	Trivial
Total SRT score	r = -0.226 p = 0.024	r = -0.089 p = 0.377	r = -0.255 p = 0.011	r = -0.100 p = 0.324
95% CI	-0.434 to 0.048	-0.277 to 0.096	-0.450 to - 0.055	-0.299 to 0.103
Hopkins descriptor	Small	Trivial	Small	Trivial

Notes: Descriptors for effect sizes are based on Hopkins (2009).

CORRELATION BETWEEN TESTS

Normalized YBT right and left anterior reach direction and total SRT scores were ‘moderately’ correlation (Table 6). When the data set was analysed according to sex, this correlation was the same in males (Table 7), but in females, the left anterior right was ‘large’, right anterior remained ‘moderate’, and right posterior medial was ‘moderate’ (Table 8).

TABLE6: THE NON-GENDER SPECIFIC CORRELATION OF COMPOSITE SRT, AND NORMALIZED YBT VALUES.

n: 100	Composite right anterior	Composite left anterior	Anterior right	Anterior left	Posterior medial right	Posterior medial left	Posterior lateral right	Posterior lateral left
Pearson Correlation	0.273	0.241	0.469	0.352	0.254	0.256	0.211	0.202
P value	0.006	0.016	<0.001	<0.001	0.011	0.010	0.035	0.044
95% CI Lower-Upper limit	0.098, 0.434	0.072, 0.421	0.305, 0.596	0.132, 0.515	0.045, 0.442	0.069, 0.449	0.015, 0.397	0.026, 0.380
Hopkins descriptor	Small	Small	Moderate	Moderate	Small	Small	Small	Small

Notes: Calculation based on total SRT, and normalized YBT reach values. Descriptors for effect sizes are based on Hopkins (2009).

TABLE7: CORRELATION BETWEEN COMPOSITE SRT AND NORMALIZED YBT VALUES IN MALE PARTICIPANTS.

n = 69	Composite right anterior	Composite left anterior	Anterior right	Anterior left	Posterior medial right	Posterior medial left	Posterior lateral right	Posterior lateral left
Pearson Correlation	0.208	0.213	0.431	0.335	0.177	0.236	0.172	0.189
P value	0.086	0.078	0.000	0.005	0.145	0.051	0.156	0.120
95% CI Lower- Upper limit	-0.019, 0.417	-0.008, 0.426	0.231, 0.595	0.079, 0.544	-0.082, 0.410	-0.012, 0.480	-0.054, 0.380	-0.007, 0.386
Hopkins descriptor	Small	Small	Moderate	Moderate	Small	Small	Small	Small

Notes: Calculation based on total SRT, and normalized YBT reach values. Descriptors for effect sizes are based on Hopkins (2009).

TABLE8: CORRELATION BETWEEN COMPOSITE SRT AND NORMALIZED YBT VALUES IN FEMALE PARTICIPANTS.

n=31	Composite right anterior	Composite left anterior	Anterior right	Anterior left	Posterior medial right	Posterior medial left	Posterior lateral right	Posterior lateral left
Pearson Correlation	0.295	0.172	0.556	0.389	0.426	0.342	0.227	0.185
P value	0.107	0.354	0.001	0.031	0.017	0.060	0.220	0.318
95% CI	-0.131, 0.634	-0.261, 0.547	0.130, 0.784	-0.147, 0.704	-0.012, 0.761	-0.032, 0.667	-0.269, 0.613	-0.312, 0.562
Lower-Upper limit								
Hopkins descriptor	Small	Small	Large	Moderate	Moderate	Moderate	Small	Small

Notes: Calculation based on total SRT, and normalized YBT reach values.

DISCUSSION

The aims of this study were to (1) to determine the strength of association between SRT and YBT scores, (2) to determine the strength of association between participant characteristics (age, weight, height, gender, activity level, self-reported physical health), SRT, and YBT scores; and (3) to generate preliminary reference data, including floor and ceiling effects, and convergent validity for both of these tests in a healthy, active adult population. There appear to be no other studies that have investigated the strength of association between SRT and the YBT. This study found a ‘moderate’ correlation between total SRT scores, and normalized YBT scores, in both the right and left anterior reach directions regardless of gender. When gender was considered, this correlation was ‘large’ in females in the right anterior reach direction, and was ‘moderate’ in the right posterior medial direction, but remained unaffected in males.

The ‘small’ negative correlation between the sitting component of SRT and age may indicate that older participants opted to use more support during the test. This may be related to physiological changes associated with ageing such as reduced neural drive in addition to reduced skeletal muscle mass and quality (Mau-Moeller, Behrens, Lindner, Bader, & Bruhn, 2013), or perhaps a decline in the function of the vestibular system (Cohen, Heaton, Congdon, & Jenkins, 1996). In addition to the physiological changes associated with ageing, additional factors of psychological origins such as the tendency to employ a more cautious strategy (Lythgo, Begg, & Best, 2007) in order to better control the SRT task might also contribute to the ‘small’ negative association between age and SRT performance.

The ‘small’ negative correlation between the SRT raising component and bodyweight suggests that heavier participants experience an increased level of difficulty performing this component of the test. This may indicate that concentric strength in relation to one’s body weight could be a contributor to SRT performance. The absence of negative correlation between participant’s self-reported health and SRT scores is consistent with the findings of De Brito et al. (2012) who reasons for the same relationship between indicators of musculoskeletal fitness (such as SRT performance) and subsequent all-cause mortality (E.g. De Brito et al, (2012) points out that good SRT scores relate to reduced mortality in the elderly.)

The large number of participants scoring a perfect 10 was more than that of the 15% required by Terwee et al. (2007) to indicate a ceiling effect. This indicates a limited level of responsiveness of the SRT in relation to this sample and signals its inability to differentiate functional abilities on the basis of SRT between the large cluster of people who scored a perfect score. This, however, does not mean that SRT is not a valid or reliable marker of musculoskeletal health as proposed by De Brito et al (2012). It is important to highlight that the research conducted by De Brito et al (2012) had a mean \pm SD age of 63 ± 8.1 years, with an age range of 52–77 years, while here the sample mean age was younger with mean for males 29.8 ± 11.1 years and 29.8 ± 8.9 years for females. Therefore, in essence, this research recruited a much younger sample than De Brito et al (2012), and was expected to have fewer functional limitations than are more typically found in older populations.

STUDY STRENGTHS AND LIMITATIONS

STRENGTHS OF THIS STUDY

Strengths of this study were the consistency in the method of Y-balance test protocol application between each participant. Each participant observed a demonstration of YBT by the researcher to ensure their understanding of the required tasks. Further, participants were allowed to perform several practice trials to minimise the impact of potential learning effects as previously identified by Hertel et al. (2000). While there have been no previous studies investigating learning effect in SRT performance, the same opportunity for practice trials was also allowed in order to minimise its potential impact. In addition to the practice trials, each participant was shown an illustration that provided a visual aid for optimal SRT performance. In order to minimise bias associated with uncertainty about what was required the researcher also provided verbal clues if the possibility for a better SRT performance was observed. This approach is an adaptation of the test descriptions offered by de Brito et al (2012) however, it was judged that for reasons relating to construct validity it was important that each participant performed the test to the best of their physical ability.

A bias that was not easily controlled for in this study was the timing related to testing and fatigue originating from a recently (in some instances less than 20 minutes) completed physical training session. In order to minimise the effect of fatigue, participants known to have undertaken recent training were required to read and sign the information sheet, participant's physical characteristics were recorded, and questionnaires had to be filled out. These procedures together can take up to 20 minutes, therefore, providing a buffer of no physical activity thus mitigating possibility of recently sustained fatigue that might impair test performance. It is important to mention that the phenomenon of recent training session applied to less than 15% of participants. Less than a third of these (approximately n=5) participated in physical activity involving the lower extremity exclusively, while most of them undertook some sort of upper body work out. None of these participants complained of general fatigue, reported low energy levels, or showed signs of impaired physical abilities (muscular shaking, excessive muscular soreness, sudden drop in performance between attempts, negative mood change associated with diminished motivation to participate) during the data collection process.

LIMITATIONS

A number of limitations should be acknowledged. Firstly, the study had a relatively small sample size of 100 participants (as indicated by poor precision in many of the confidence intervals) and while the precision could be improved by a larger sample, the resource constraint of remaining within the limited scope of a 90-credit thesis made this unfeasible. Secondly, participants represented in this sample were formed from a convenience sample rather than by random sampling. Therefore, the sample here may not be representative of the general, active, healthy, population of New Zealand. Thirdly, females represented approximately only a third of the sample, and as such, they are proportionally underrepresented thus the outcome might have been influenced by the relatively small number of females participating in the study. Therefore, the external validity of this research should be considered in light of these limitations.

A further limitation related to external validity is that one investigator facilitated the measurement sessions. While the investigator undertook extensive familiarisation with SRT instructional materials before undertaking any data collection (Araújo, 2011), it might be possible that ratings made by the investigator may differ from other raters. Although De Brito et al (2012) cites their own previous work as evidence of good SRT rater reliability, it was not possible to appraise risk of bias because the article was not published in English (Lira & de Araújo, 2000).

Future research could be undertaken in order to investigate reliability by independent researchers outside of De Brito et al research group. Regardless, the fact that only one rater assessed all participants eliminates some potential problems with inter-rater reliability, but in principle does negatively impact the generalizability of this research.

Finally, the self-report questionnaires used for PA and health are known to carry a certain level of bias in reporting. Boon et al. (2008) have shown that self-report questionnaires tend to overestimate activity levels. However, no other logistically feasible options to objectively determine PA or health was available for this particular project. Nevertheless, IPAQ has been shown to be as valid and reliable as other established self-report questionnaires (Booth et al., 2003) and is widely utilised.

IMPLICATIONS FOR CLINICAL PRACTITIONERS

The correlation findings indicate that to a limited level, some similar underlying constructs are contributing to test performance in both SRT and YBT. However, the correlation between the tests is not substantial enough to enable practitioners to interchangeably apply these tests for musculoskeletal evaluation. Additionally, the ceiling effect observed in this sample of healthy, active adults indicates that SRT is not a suitable measurement tool in younger adults as it may generate an unacceptably high number of false negatives (i.e. score high but have poor musculoskeletal health) as a generic measure of musculoskeletal health. Therefore, when someone who is perceived to be healthy and physically active (but scores low on the SRT) this represents an outcome that should attract extra clinical attention from the practitioner who is facilitating the test. Finally, this data set and its findings could be used to establish a normative data set for a young, healthy and active set of population. A data set for such people would aid clinical work by providing reference values and benchmark performance indicators for the YBT and SRT.

IMPLICATIONS FOR RESEARCHERS

Future research may seek to investigate a possible correlation between SRT performance and strength (normalized for lean body mass for both genders), as well as SRT performance and flexibility and / or mobility correlations of the lower extremity in an age group that is older than that represented by this research project.

CONCLUSION

This study was performed to ascertain (1) the strength of association between SRT and YBT scores, (2) the strength of association between participant characteristics (age, weight, height, gender, activity level, self-reported physical health), SRT, and YBT scores; and finally (3) normative data, floor and ceiling effects, and convergent validity in both of these tests in a healthy, active adult population. This study found (1) a ‘moderate’ correlation between total SRT scores, and normalized YBT scores, in both the right and left anterior reach directions regardless of gender. When gender was considered (2), this correlation was ‘large’ in females in the right anterior reach direction, and was ‘moderate’ in the right posterior medial direction, but remained unaffected in males. Additionally, (2) a ‘small’ negative correlation between the sitting component of SRT and age. As well as a ‘small’ negative correlation between the SRT raising component and bodyweight were found. The investigation for ceiling effect (3) found that the large number of participants scoring a perfect 10 was more than enough to reach the 15% threshold required to achieve such ceiling effect. The correlation findings (3) between SRT and YBT suggest that to a limited level, some similar underlying constructs are contributing to test performance in both SRT and YBT. However, the correlation overlap between the tests is not substantial enough to enable practitioners to interchangeably apply these tests for musculoskeletal evaluation. Additionally, no correlation was found between the participant’s height, height-leg length ratio and SRT sitting component performance. Furthermore, no correlation with participant’s height, height-leg length ratio and raising component of SRT performance was identified.

CONFLICT OF INTEREST:

The author has no financial or other interest in either the instrumented Y-balance test or Sitting-Raising test.

FUNDING:

No external funding.

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APPENDICES

Section 3: Appendices

Appendix A: Ethics approval

Attila Kruchio
8/16 Wiremu Street
Mount Eden 1041
Auckland 1041

18.6.15

Dear Attila,

Your file number for this application: **2015-1036**

Title: **An investigation of the relationship between the Y-balance test and sit-to-raise test in an active population.**

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

Start date: 18.6.15

Finish date: 18.6.16

Please note that:

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

You may now commence your research according to the protocols approved by UREC.

We wish you every success with your project.

Yours sincerely,



Sara Donaghey
Deputy Chair, UREC

cc: Rob Moran
Cynthia Almeida



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Appendix B: Participant information sheet

Participant information sheet

An investigation of the relationship between the Y-balance and sit-to-raise test in an active population

You are invited to participate in our research investigation. Please read carefully through this information sheet before you make a decision about volunteering.

What's the purpose of study?

The purpose of this study is to investigate two separate tests that are used to explore movement quality from seemingly opposing ends of the movement quality spectrum. One is often applied as a pre-season screening tool in athletic populations such as rugby or basketball teams in order to evaluate the risk of potential lower extremity injury. While the other test has been used to assess movement quality from a health point of view.

What are the criteria for participating?

You are eligible to participate if you are aged 18 or over and physically active. You will not be eligible to participate if you:

- Have a history of vestibular disorder (middle ear) or other disorder known to impair balance.
- Had a serious lower extremity injury that required medical attention in the past 6 weeks.
- Have acute lower back pain.
- Presence of musculoskeletal abnormalities that would prevent or interfere with the execution of either tests.
- Taking any medication that may alter balance or cause drowsiness.

If I choose to volunteer, what will be required?

Should you agree to participate in the study, you will be invited to attend a 20-minute session at a time of your convenience.

1. During this 20-minute session your height and weight will be measured.
2. You will be asked to complete two short questionnaires about your level of physical activity and about your health status.
3. You will be asked to perform two short movement tests that assesses your movement quality/dynamic balance (Figure 1 and 2)



Figure 1 The instrumented Y-balance test

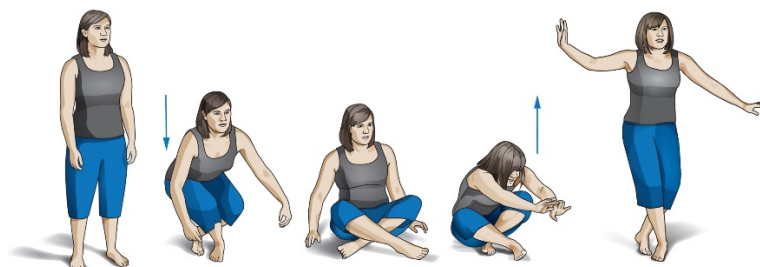


Figure 2 The sit-to-raise test

What will happen to the information I provide and how will my privacy be protected?

The information you provide will be kept confidential to the researchers and your name or other personally identifying information will not be included in any report arising from the research. All the data collected from our participants during the study will be anonymized and will be stored securely on a password protected file. Access to this data will be limited to the researchers. You can withdraw your data and any other information from the study up to 1 week following the data collection session. This would mean that even though you have provided data we could remove it from the study if you wished to do this for any reason. To do this you would need to contact us using the details below.

Who can I contact for further information, concerns or queries?

Please feel free to contact us at any time if you have any concerns, queries or require any further information about the research project.

Principal researcher:

Attila Kruchio

Tel: 021-800-976

Email: ybt.srt@gmail.com

Research Supervisor:

Rob Moran

Tel: 021 073 9984 or 09 815 4321 ext 8197

Email: rmoran@unitec.ac.nz

Thank you very much for your participation. If you have any questions at any time during the course of the study or following the completion of the study, please don't hesitate to contact us.

UREC REGISTRATION NUMBER: 2015-1036

This study has been approved by the Unitec Research Ethics Committee from 18.06.2015 to 18.06.2016. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 7248). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix C: Participant consent form



Participant Consent Form

Name of Participant: _____

I have seen the information sheet about this study. I have read and understand the information sheet given to me. I have had the opportunity to discuss any queries or concerns regarding this study with the principal researcher, Attila Kruchio, and am satisfied with the explanations given.

I understand that taking part in this project is my own choice. I don't have to be part of this if I don't want to and I understand that I may withdraw from this study up to 1 week from the date of data collection. I also understand that withdrawing from the study will not affect my access to any services provided by Unitec Sport Centre.

I understand that information I provide during the study will be confidential, and that only Attila Kruchio and the thesis supervisors will have access to the information you provide.

I understand that all the information that I give will be stored securely on a computer at Unitec for a period of 10 years and that any information reported will not identify me in any way. I give permission for the data from this study to be retained and combined with other future studies provided that my identity remains anonymous.

I consent / I do not consent (strike as necessary) to ongoing use of short video clips beyond this research as part of other future research studies or for the purposes of educating health and exercise practitioners. All video clips used beyond this study will include digital pixilation of the face so that I cannot be identified.

I understand that I can see the finished research document.

I have had time to consider everything and I give my consent to be a part of this study.

I know whom to contact if I have any questions or concerns about this project.

The principal researcher is:

Attila Kruchio

E-mail: akruchio@gmail.com

Mob: 021-800-976

Participant's Name: _____

Participant's signature: _____ Date: _____

Project explained by: _____

Signature: _____ Date: _____

Please indicate if you wish to receive a copy of the results: YES ☐ NO ☐

The participant should retain a copy of this consent form

UREC REGISTRATION NUMBER: 2015-1036

This study has been approved by the Unitec Research Ethics Committee from 18.06.2015 to 18.06.2016. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 7248). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix D: The poster that was used to advertise the study.



Research participants required

Project title: An investigation of the relationship between the Y- balance and sit-to-raise test.

- Are you aged 18 or over?
- Without a history of middle ear or balance disorders.
- Free of any lower extremity injury that required medical attention in the past 6 weeks.
- Currently not experiencing any low back pain.
- Free of musculoskeletal abnormalities that would prevent or interfere with the execution of these simple tests.
- You do not take any medication known to alter balance or cause drowsiness.
- You are able to walk without assistance.

I need 20 minutes of your time to investigate any existing relationship between two simple movement tests that assess your dynamic balance and mobility. One frequently implemented in pre-season in order to screen sporting teams for the likelihood of lower-body injury, while the other is more concerned with health related quality of life.



Who can I contact for further information, concerns or queries?

Please feel free to contact us at any time if you have any concerns, queries or require any further information about the research project.

Principal researcher:

Attila Kruchio

Tel: 021-800-976

Email: ybt.srt@gmail.com

Research Supervisor:

Rob Moran

Tel: 021 073 9984 or 09 815 4321 ext 8197

Email: rmoran@unitec.ac.nz

Thank you very much for your participation.

Appendix E: Questionnaires used in the study.

Your Health and Well-Being

This questionnaire asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. *Thank you for completing this questionnaire!*

For each of the following questions, please mark an ☐ in the one box that best describes your answer.

1. In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
▼	▼	▼	▼	▼
<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5

2. The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
	▼	▼	▼
a <u>Moderate activities</u> , such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3
b Climbing <u>several</u> flights of stairs	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3

3. During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a	▼	▼	▼	▼	▼
<u>Accomplished less</u> than you would like	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
b					
Were limited in the <u>kind</u> of work or other activities	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5

4. During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a	▼	▼	▼	▼	▼
<u>Accomplished less</u> than you would like	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
b					
Did work or other activities <u>less carefully than usual</u>	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5

5. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
▼	▼	▼	▼	▼
<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5

6. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks...

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
	▼	▼	▼	▼	▼
a Have you felt calm and peaceful?.....	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
b Did you have a lot of energy?	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
c Have you felt downhearted and depressed?.....	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5

7. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
▼	▼	▼	▼	▼
<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5

Thank you for completing these questions!

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (October 2002)

LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health-related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ

International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective*. Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ Yes

☐ No →

Skip to PART 2: TRANSPORTATION

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity



Skip to question 4

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**

_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity



Skip to question 6

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐

No job-related walking



Skip to PART 2: TRANSPORTATION

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐

No traveling in a motor vehicle



Skip to question 10

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐

No bicycling from place to place



Skip to question 12

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐

No walking from place to place



***Skip to PART 3:
HOUSEWORK, HOUSE
MAINTENANCE, AND
CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐

No vigorous activity in garden or yard



Skip to question 16

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐

No moderate activity in garden or yard



Skip to question 18

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐

No moderate activity inside home



***Skip to PART 4:
RECREATION, SPORT AND
LEISURE-TIME PHYSICAL
ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐

No walking in leisure time



Skip to question 22

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐

No vigorous activity in leisure time



Skip to question 24

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**

_____ minutes per day

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ days per week

☐

No moderate activity in leisure time



Skip to PART 5: TIME SPENT SITTING

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?

_____ hours per day

_____ minutes per day

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ hours per day

_____ minutes per day

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ hours per day

_____ minutes per day

This is the end of the questionnaire, thank you for participating.

Appendix F: Data collection sheets.

YBT data collection sheet

Date:

Participant:

Sex:

Age:

Height:

Weight:

Right leg length:
(ASIS to R Maleola)

Left leg length:
(ASIS to L Maleola)

Right anterior reach

1:

2: Best:

3:

Left anterior reach

1:

2: Best:

3:

Right posterior medial

1:

2: Best:

3:

Left posterior medial

1:

2: Best:

3:

Right posterior lateral

1:

2: Best:

3:

Left posterior lateral

1:

2: Best:

3:

Composite scores calculated as:

$\frac{3 \text{ best reaches added together for the side}}{3 \times \text{limb length}}$ than multiply it by 100

Right composite number:

Left composite number:

SRT data collection sheet

Date:

Participant:

Attempt 1

Sitting down score

Standing up score

Attempt 2

Sitting down score

Standing up score

Attempt 3

Sitting down score

Standing up score

HIGHEST scores for each action

(Sitting down)

/

(Standing up)

Appendix G: E-mail communication to use image from Discover magazine.

From: Attila Kruchio <akruchio@gmail.com>

To: roenkelly@sbcglobal.net

Sent: Monday, July 4, 2016 3:34 AM

Subject: Seeking permission to use one of your drawing in my school project / master thesis.

Hello

I would like to ask for permission to use an image featured in the article "Simple sitting test predicts how long you will live." Published under the URL: <http://discovermagazine.com/2013/nov/05-sit-down>

If it is possible I would like to use (and reference you as the artist) the following image from the above mentioned article. With your permission I would use your art in my Postgraduate Thesis.

My thesis was aimed at evaluating any existing association between the Y-balance test and the pictured Sitting Raising test.

If you have any additional question, please don't hesitate to contact me.

Kind regards

Attila Kruchio

Postgraduate student
Unitec
Auckland
New Zealand

Dan Bishop <dbishop@discovermagazine.com>

Hello Attila.

Yes, you may use the illustration.

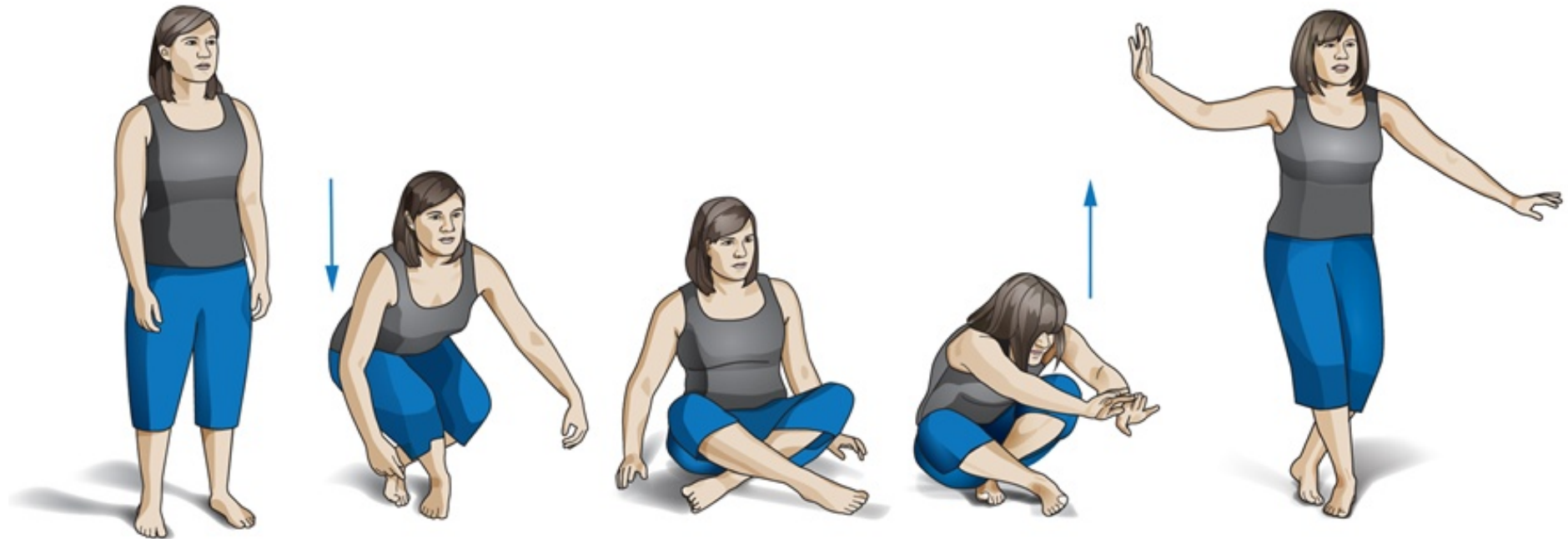
Please credit Roen Kelly/Discover

Thanks.

Dan Bishop

Design Director | DISCOVER magazine
Kalmbach Publishing Co. | 262.798.6562

Appendix H: Picture utilised for the purpose of visual cue during the Sit-to-Raise-Test



Artist: Roen Kelly, image as featured in discovery magazine's online article "Simple sitting test predicts how long you will live.", published under the URL: <http://discovermagazine.com/2013/nov/05-sit-down>

Full name of author: Attila Kuchis

Full title of thesis/dissertation/research project ('the work'):

An investigation of the relationship between the
Y-balance Test and Sit-to-Raise-Test in a sample
of active healthy adults: A cross-sectional correlation
design.

Practice Pathway: Health care

Degree: Osteopathy (Masters)

Year of presentation: 2016

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Attila Kuchis

Signature of author: Attila Kuchis

Date: 07.1.09.1.2016



Declaration

Name of candidate: Attila Kruchio

This thesis entitled: "An investigation of the relationship between the Y-Balance Test and the Sit-to-Raise-Test in a sample of active healthy adults: A cross-sectional correlation design." is submitted in partial fulfillment of the requirements for the Unitec degree of Master of Osteopathy.

Candidates Declaration

I confirm that:

- This thesis represents my own work;
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: UREC 2015-1036

Candidate Signature:

Attila Kruchio

Date:

07/09/2016