ECCENTRIC SQUAT LOADING AS MEANS OF ASSESSING PHYSICAL FUNCTION IN SENIORS

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ABSTRACT

Healthy aging is a key concern for Canada's aging population. Investigating methods that assist and promote healthy aging is therefore important to inform on this matter. The maintenance of functional ability, rather, the ability to conduct everyday tasks and perform the functions necessary for everyday life is crucial to assist in the healthy aging process (Lehto et. al., 2017, Arena et. al., 2007). In regard to functional ability, muscle strength and muscle power are two key factors in defining performance. A method of properly assessing these outputs leads to a determination of an individual's functional performance level and potential interventions to mitigate declining function with age. Traditionally, muscle strength and power have been assessed using an isokinetic dynamometer, but this comes with limitations such as its high cost and the accessibility.

Muscle strength and muscle power have commonly been maintained through strength and power training. This type of training has limitations that eccentric training may overcome. Isoinertial flywheel devices, such as the kBox (Exxentric), not only have the potential to produce eccentric overload necessary for eccentric training, but they are also capable of recording velocity and power outputs. The kBox may be beneficial to the aging population to determine functional ability and provide a method for eccentric training while overcoming the limitations of the dynamometer. Therefore, investigation into the kBox capabilities regarding the reliability and validity of measured outputs as well as the potential to predict functional ability is necessary.

This study had three objectives: 1) To determine the relationship of the kBox power outputs in comparison to the "gold standard" dynamometer. Researchers hypothesized that the kBox would display good validity and be correlated with the measured outputs of the dynamometer; 2) To determine if the kBox measured outputs and/or the dynamometer measured outputs predicted functional performance by comparing outputs to three functional tests. Researchers hypothesized that the kBox would be more predictive of functional performance due to its multi-joint movement; 3) To investigate sEMG and muscle oxygenation levels across the various modalities tested to gain insight into the physiological responses accompanying each movement. Researchers hypothesized the kBox SPT would produce greater muscle activation as well as greater muscle deoxygenation compared to testing on the isokinetic dynamometer.

A total of 26 strength trained individuals (62.6 ± 6.2 yrs old) were recruited and volunteered to participate in this study. Participants completed three functional tests; the timed-up-and-go test, the five time sit-to-stand test, and the stair climb power test. Participants also completed the kBox Squat Power Test (SPT) as well as dynamometer concentric, isometric and eccentric tests. Muscle activation and muscle oxygenation were recorded across modalities when possible.

For the first hypothesis, Pearson's correlations displayed the flywheel SPT to have high correlations with the dynamometer power and strength outputs, confirming the SPT has high concurrent validity when measuring a senior population during the SPT protocol. For the second hypothesis, the dynamometer results were more predictive of outcomes on the three functional tests than the kBox (Pearson's correlation and stepwise multiple linear regression tests). Last, no significant differences between muscle activation or muscle oxygenation were found across modalities through ANOVA and Tukey post-hoc tests.

Results of this study display the potential the isoinertial kBox has for future clinical settings. The good relationship/validity, along with the prediction of some functional tests demonstrates its usage for further studies and quantification of muscle outputs for various exercises. These findings suggest the kBox may be used in the future to determine functional performance, overcoming the limitations of the dynamometer. Additionally, this study displayed the SPT protocol can be conducted safely and successfully by a senior population meaning the kBox can overcome the limitations set forth by traditional strength and power training such as a decrease in cost for the equipment and easier accessibility for senior population.

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LIST OF ABBREVIATIONS

GH	Human Growth Hormone
IGF-1	Insulin-like Growth factor-1
ATP	Adenosine Triphosphate
HR	Heart rate
TUG	Time-Up-and-Go
6MWT	6-Minute walk test
SCPT	Stair Climb Power Test
FTSTS	Five time sit-to-stand
GS	Gait Speed
RTD	Rate of torque development
EMG	Electromyography
sEMG	Surface electromyography
MUAP	Motor unit-action potential
VL	Vastus Lateralis
VM	Vastus Medialis
RF	Rectus Femoris
MVIC	Maximum Voluntary Isometric Contraction
MVC	Maximum Voluntary Contraction
MO	Muscle Oxygenation
NIRS	Near-infrared Spectroscopy
TOI	Tissue Oxygenation Index
ROM	Range of Motion
SPT	Squat Power Test
GAQ	Get Active Questionnaire
QST	Quiet Standing Trial
ICC	Intraclass Correlation
ECC	Eccentric
CON	Concentric

Chapter 1: INTRODUCTION

1. Introduction to Eccentric Squat Loading to Measure Functional Performance

Canada's older adult population is increasing at a high rate. By 2017, the country's population was comprised by a majority of individuals age 60 and above. It is important to investigate and ensure methods that promote healthy aging, such as diet and various forms of exercise, are confirmed and utilized. The aging process begins with regressions of all body systems, which affect an individual's ability to perform daily tasks, their functional ability and quality of life (Algilani et. al., 2014; Hunter et. al., 2004; Chodzko-Zajko et. al., 2009). Age-related changes may be conceptualized under three key physiological categories: hormonal, neural, and muscular. Adaptations within these body systems interplay and attribute to age-related declines. A common decrease is one's muscle strength and power (Chodzko-Zajko et. al., 2009). Muscle strength and power are key components of physicality that are associated with daily movements and determine functional ability (Hairi et. al., 2010; Pizzigalli et. al., 2011).

Muscle strength is the ability of a muscle group to generate force against a resistance/load (Brown & Weir, 2001; Bonder & Bello-Haas, 2018). Lower body strength declines during the aging process and is critical for day-to-day life as well as functional ability (Bonder & Bello-Haas, 2018). It has been noted in previous literature when well-established lower body muscle strength is present, good stability, posture, function and mobility are also present. Muscle strength can be assessed through many different methods including functional tests, the Oxford Scale, manual muscle tests, weightlifting (repetition maximum), and in research and clinical settings, through the use of an isokinetic dynamometer (Jaric, S. 2002; Bonder & Bello-Haas, 2018; Siff, M.C, 2008). An isokinetic dynamometer is a system used to test and quantify joint performance, muscle function and assist in the diagnosis and treatment of various pathologies (Computer Sports Medicine, 2006). The quantification of muscle strength is imperative when predicting and understanding functional performance. In quantifying muscle strength, it has been noted that eccentric muscle strength declines to a lesser degree than other types of muscle strength. This indicates the importance of eccentric strength as one ages (Bonder & Bello-Haas, 2018; Roig et. al., 2010).

Muscle power is similar to muscle strength but is a separate parameter when assessing and predicting one's physical state (Bean et. al., 2002; Bonder & Bello-Haas, 2018). Muscle power is the ability to generate force rapidly and therefore includes both force and speed (Bean et. al., 2002; Bonder & Bello-Haas, 2018). Lower body muscle power is also an important factor to quantify due to its predictability of functional performance as muscle power is associated to daily movements such as climbing stairs, rising from a chair, and walking (Evans, W., 2000; Skelton et. al., 2002; Henwood et. al., 2008; Reid & Fielding, 2012). In typical settings, muscle power is quantified by various methods such as power lifting using free weights, the use of resistance machines, or other instruments (Alcazar, J. et. al., 2018). In research settings, quantifying muscle power is often done using an isokinetic dynamometer. The use of an isokinetic dynamometer allows for a predetermined speed to be set and controlled ensuring a reliable measure of muscle power (Bonder & Bello-Haas, 2018). Similar to muscle strength, eccentric muscle power decreases at a lesser rate in comparison to concentric muscle power highlighting its importance in an aging population (Bonder & Bello-Haas, 2018).

The technology employed in an isokinetic dynamometer allows for real time quantification of muscle strength, power, and endurance of many muscle groups including those around the shoulders, knees, elbows, wrists, hips, ankles and back (Computer Sports Medicine, 2006). The quantification of muscle strength and power is important when predicting functional performance. There is much clinical research that supports valid measurements of muscle strength and power produced through dynamometer assessments (Habets et. al., 2018; Computer Sports Medicine, 2006). The benefits of using an isokinetic dynamometer as a tool of evaluation include high levels of accuracy, a reduced chance of overload injury, a full range of speed for testing various exercises, decreased compression on joints, and the most efficient use of muscle output.

Limitations of isokinetic dynamometers exist when measuring muscle strength, power and predicting functional performance. The first limitation noted is the cost of the equipment. The price of an isokinetic dynamometer may act as a deterrent for clinicians, limiting its accessibility and usage (Nomura et. al., 2018). Additionally, an isokinetic dynamometer is a large piece of equipment. Due to the size, it is not transportable, resulting in decreased access and possible travel requirements for patients. Last, the assessment of lower limb strength is conducted through the motion of knee extension. This movement does not encompass all motions associated with daily tasks, limiting the predictability of functional performance. These limitations may be overcome through the exploration of a flywheel device that utilizes eccentric training through a squatting motion.

Eccentric lower body strength and power components are key when relating and predicting functional performance in a senior population. Eccentric training and eccentric overload methods may be critical to examine when considering a healthy aging process for Canadians. Eccentric actions are characterized as activation during the lengthening of muscles, such that there is a stretch in the musculotendinous complex most commonly described as a breaking force (Isner-Horobeti et. al., 2013; Gault & Willems, 2013; Hedayatpour & Falla, 2015). The development of flywheel devices, allows and promotes eccentric training, in particular lower body eccentric training, due to its ability to apply variable resistance through all phases of a contraction. It has been noted through literature the practice of eccentric training in an older adult population combats sarcopenia more so than traditional resistance training (Tesch et. al., 2017). In addition, eccentric training encompasses key benefits for a senior population. Eccentric training results in increased force/power production, decreased metabolic demand, decreased cardiovascular demand, increased muscular adaptation and hypertrophy, and increased muscle strength and power (Isner-Horobeti et. al., 2013; Bonder & Bello-Haas, 2018; Gaul & Willems, 2013; Hedayatpour & Falla, 2015). Therefore, harnessing eccentric training is beneficial for a senior population, relating to functional performance and the ability to perform daily activities. Although identified benefits exist of eccentric training, the question remains as to whether eccentric overload training is predictive of functional performance results. Eccentric overload is a concept that expands upon eccentric training. There is little literature exploring the concept of eccentric overload training in a senior population, its predictability of functional performance, and the physiological benefits it may produce.

One potential method of achieving eccentric overload is through the use of flywheel training. For example, the kBox4 (Exxentric) is popular among young, strength trained populations and competitive athletes. This system utilizes the flywheel capabilities to provide high and variable resistance through a full range of motion (Exxentric, 2019). This makes the kBox4 capable of eccentric training as well as eliciting eccentric overload. The kBox4 is capable of measuring and quantifying both muscle strength and power as well as real time data including speed rotations and time (Exxentric, 2019). These measurements are important when assessing function and therefore this device may be applicable in clinical settings. In addition to muscle function measurements, the kBox4 may overcome the limitations set forth by the isokinetic dynamometer. The kBox4 device is more affordable than an isokinetic dynamometer, and is transportable, increasing its accessibility and evaluation opportunities. Last, the lower body evaluation conducted is through the motion of a squat and this movement encompasses and mimics daily tasks more so than single joint motions, and therefore could be more predictive of functional performance in an aging population.

In understanding the importance of evaluating muscle strength, muscle power and predicting functional performance as well as the importance eccentric strength, power and action play in daily activities, the kBox4 is an important tool to be investigated. There is no known research examining the applicability of the kBox4 in a clinical setting and little literature explores lower body eccentric overload applications in a senior population, especially in regard to its ability to be predictive of functional performance. Therefore, this study aimed to examine the ability of eccentric load squatting on the kBox4 in predicting functional ability, as well as compare physiological measures such as muscle oxygenation and electromyography to provide insight into these various actions.

Study Objectives:

1. To determine the relationship of the isoinertial kBox flywheel measured outputs in comparison to the gold standard isokinetic dynamometer.
2. To determine if the kBox and/or the dynamometer are predictive of functional performance.
3. To investigate the physiological responses associated with the kBox flywheel SPT, isokinetic dynamometer tests, FTSTS, SCPT and TUG using surface EMG and muscle oxygenation.

Study Hypotheses:

1. The isoinertial kBox flywheel power and torque outputs during squatting will correlate strongly with the gold standard isokinetic dynamometer power and torque outputs during knee extension.
2. The isoinertial kBox flywheel power and torque outputs during squatting will be more predictive of functional performance tests than the isokinetic dynamometer power and torque outputs as the kBox uses whole-body movement evaluation (SPT).
3. Muscle oxygenation and muscle activation will be greater during the kBox flywheel squatting and the functional tests performed due to the similar movements (whole body) and therefore the resulting physiological demands.

Chapter 2: LITERATURE REVIEW

2.1 Normal Aging and Mitigation

Normal aging is accompanied by multiple physiological adaptations and regressions in all body systems which are interconnected and interdependent (Butcher & Nowak, 2016; Bonder & Bello-Hass, 2018; Algilani et. al., 2014). Changes that accompany normal aging are unique for each individual due to personal factors, environmental factors as well as one's physiological baseline and aging rate (Bonder & Bello-Hass, 2018; Chodzko-Zajko et. al., 2009). Although unique, age-related changes are vast and evident due to the effects they afflict the ability to perform daily tasks, functional abilities, concept of independence and overall quality of life (Algilani etl. Al., 2014; Hunter et. al., 2004; Chodzko-Zajko et. al., 2009).

The importance of healthy aging is becoming more imperative now than ever due to the aging population of Canada. The most recent census conducted by Statistics Canada (2018) accounted for approximately six million people 65 years or older, with the population of individuals in their 60's growing the most rapidly in the country. By 2017, senior individuals outnumbered the population of children, which is a milestone in Canadian history (Statistics Canada, 2018). Therefore, the investigation, conceptualization and understanding of age-related physiological adaptations is critical when providing clinical evaluations, methods, and prescriptions to assist Canadians in the healthy aging process.

2.2 Physiological Adaptations to Aging

2.2.1 Hormonal, Neural and Muscular Adaptations

In general, age-related changes can be described by dividing concepts under three main physiological categories; hormonal changes, neural changes, and muscular changes. Although divisions can be made in order to conceptualize these adaptations, they are not exclusive (Bonder & Bello-Haas, 2018). The endocrine system changes as we age, altering the levels of hormones produced and secreted into the body (Straub et. al., 2001). Some hormone levels increase, others are maintained, while some decrease. A decrease in hormone production and secretion has known physiological effects on an individual's functional performance and is therefore of great importance. Steroid hormones including estrogen, testosterone and aldosterone decrease with age resulting in decreases of bone mass, muscle mass, body hair, strength, and an increase in adipose tissue. Human Growth Hormone (GH) decreases with age which effects muscular growth, bone growth, insulin-like growth factor 1 (IGF-1), and one's sarcomere hypertrophy as well as protein synthesis capabilities. The decrease in IGF-1 plays a large role in promotion of all cell growth and in this case, the lack thereof (Bonder & Bello-Haas, 2018; Snyder et. al., 1999; Herbst & Bhasin, 2004; Maltias et. al., 2009).

Numerous changes occur in the neural system as one ages which can affect the performance of daily tasks, reflexes and all functional performance. These changes include and are not limited to, a decrease in dendritic branching and myelination, resulting in reduced synapse conduction. A loss of motor nerve fibers and a decrease in number and size of motor units leads to increased weakness, a general slowing of nerve conduction velocities, as well as defects in protein synthesis (Bonder & Bello-Hass, 2018). These changes in the neural system are not as rapid as in other body systems, with most healthy adults displaying minimal neuronal changes when aging, except for those with impairments (Bonder & Bello-Haas, 2018).

Age-related muscular changes are determinants for conducting daily movement and have great effect on one's functional ability. Sarcopenia, which is a loss of muscle mass, is one of many prominent muscular adaptations that occurs even in healthy, independent, older adults (Bonder&Bello-Hass, 2018; Kappus et. al., 2016; Hunter et. al., 2004). Sarcopenia accounts for a substantive loss of muscle strength as one ages. Other adaptations leading to a loss of muscle strength include decreases in the number of motor neurons as well as decreases protein synthesis and increased turnover capabilities. These two adaptations result in decreased muscle fiber number, especially type II fibers, which overall lead to decreased force production (Lexell et. al., 1988; Granacher et. al., 2008). There is an observed increase in fat and connective tissue around muscles which disrupt the normal orientation of myofilaments resulting in an increase energy cost and a reduction in tension. Other adaptations of aging occur in cartilage, joints and tendons. There is an increase in collagen leading to an increase in muscle stiffness and therefore decreased mobility. Decreases in elastin cause a decrease in the ease of movements and decreases in hyaluronic acid result in a loss of tensile strength and tissue degradation. Both decreases are proteoglycans and glycoproteins which cause less hydration of tissues (Bonder&Bello-Hass, 2018).

As identified, there are various and multiple adaptations that occur in all body systems as one ages. It is challenging to target specific aspects of these adaptations to improve upon due to their interconnectivity; therefore, finding commonalities and examining the benefits at a higher level is more effective and advantageous (Chodzko-Zajko et. al., 2009). The adaptations listed within the hormonal, neural and muscular systems are all related and affect muscle strength and power (Figure 1). Muscle strength and power are highly associated and correlate to the ability to perform daily activities such as walking, change of direction movements and balance (Hairi et. al., 2010; Pizzigalli et. al., 2011). The definition of functional ability must be understood to adequately examine combative measure of age-related changes.

2.2.2 Functional Ability/Functional Performance

The concept of functional ability as well as the loss of function as one ages has been studied and well defined. One of the early definitions regarding the process of aging was described by Rose in 1994 as "a persistent decline in fitness components due to physiological degeneration" (Rose M.R., 1994; Flatt, T., 2012). Bonder & Bello-Hass, 2018 describe aging as a progressive deterioration of physiological function which ultimately results in loss of function and increased vulnerability. These definitions have been expanded upon to include other factors of life. Algilani et. al., 2014 examined the definitions of optimal functional performance and concluded that there are three key factors; external factors such as socialization, and environment, self-related factors such as coping skills, psychological well-being, religious/spiritual beliefs and last, body-related factors including and not limited to physical activity, medications and poor health (Algilani et. al., 2014). Tate et. al. (2003) demonstrates support of these factors as well. It is important to note there is no clear standard/common underlying definition of measuring success in aging.

Difficulty arises when including subjective evaluations of functional capacity such as socialization, independence, psychological well-being and coping skills. Therefore, although the optimal definition of functional ability may include these factors, well-established protocols and standards put in place to evaluate an individuals' functional capacity are physical in nature (Bohannon R.W., 2006; Blackwood J., 2017; Westby et. al., 2015; Podsialdo & Richardson, 1991). These physical evaluations assess and relate to one's muscle strength and power which correlates to the concept that adaptations and interactions through all major body systems is key in determining one's ability to function (Arena et. al., 2007). In general, an accepted definition of functional capacity is the ability to perform daily tasks and functions necessary for everyday life (Lehto et. al., 2017; Arena et. al., 2007). Daily tasks include and are not limited to, rising from a chair, going up stairs and change of direction movements. These daily tasks and one's functional

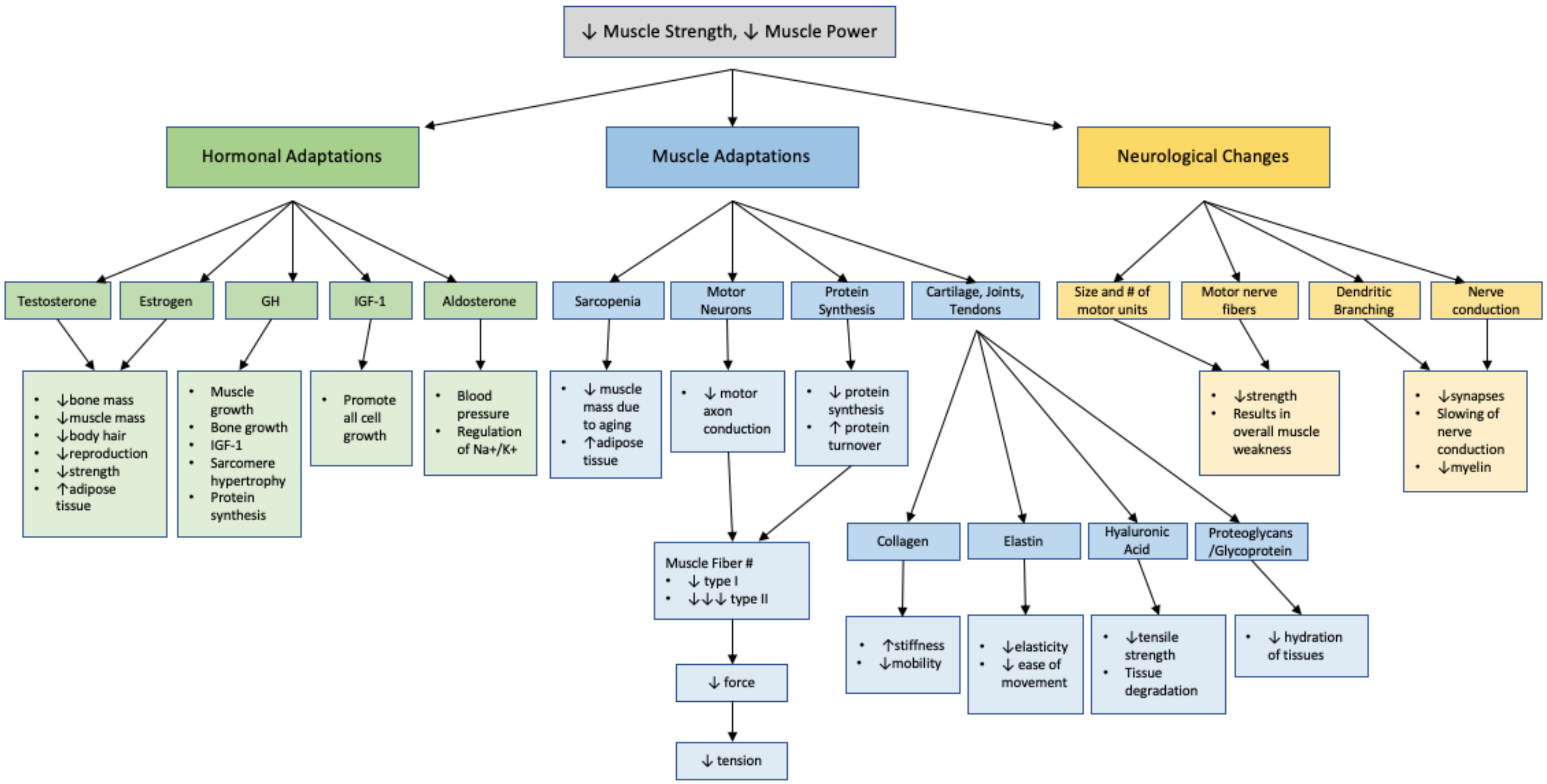


Figure 1: Adaptation of Aging Summary. As displayed, adaptations have been separated into components of hormonal adaptations, muscle adaptations, and neurological adaptations. Hormonal adaptations include changes in testosterone, estrogen, growth hormone (GH), insulin-growth factor 1 (IGF-1), and aldosterone. Muscle adaptations include sarcopenia, changes in motor neurons, changes in protein synthesis capabilities, and changes within cartilage, joints and tendons. Neurological adaptations include changes in the size and number of motor units, motor nerve fibers, dendritic branching and nerve conduction. All factors listed under their designated subgroup occur with aging and are interconnected. Information compiled from: Bonder & Bello-Haas, 2018; Straub et. al., 2001; Snyder et. al., 1999; Herbst & Bhasin, 2004; Maltais et. al., 2009; Butcher & Nowak, 2016; Kappus et. al., 2016; Hunter et. al., 2004 Granacher et. al., 2008; Chodzko-Zajko et. al., 2009.

capacity are highly related and dependent upon muscle strength and power (Foldvari et. al., 2000). Therefore, when examining mitigation of age-related changes, muscle strength and power are critical variables to consider.

2.3 Mitigation of Aging

2.3.1 Diet and Exercise

Maintaining healthy nutrition is one of many aspects that decrease frailty and increase independence as one ages (Duetz et. al., 2014; Bernstein & Munoz, 2012; Ng et. al., 2015). Exercise regimes in old-age accompanied by a healthy diet have been proven to increase functional performance and are considered optimal strategies when combating aging (Deutz et. al., 2014; Chodzko-Zajko et. al., 2009; Ng et. al., 2015). Various exercise regimes have been investigated in regard to the benefits displayed physiologically over time. The benefits of aerobic (or cardiovascular) endurance exercise noted through multiple studies include the ability to promote change in depressive and anxiety states, to improve cardiovascular health, as well as neurological benefits (Antunes et. al., 2005; Butcher & Nowak, 2016). Although endurance exercise is important to include in exercise regimes due to its multiple benefits of directly improving functional performance, it is imperative to examine methods that improve one's muscle strength and muscle power.

2.3.2 Strength/Power Training and Function Performance

Strength and power training, also known as traditional resistance training, is conducted by opposing gravitational force in addition to added weight through applying methods such as dumbbells, barbells, and other free weights or exercise machines. The additional weight applied increases muscle damage, stimulating muscle hypertrophy resulting in the building of muscles, increasing muscle mass. An increase in lower body muscle mass increases stability and functional performance (Bonder & Bello-Haas, 2018). Benefits regarding strength and power training for an older population have been documented in literature. Fatouros et. al., 2005 note that strength training is essential when improving cardiovascular health, to combat sarcopenia, to reverse the loss of muscle mass and muscle strength, and overall, to combat frailty and falling incidences. Other studies have produced similar beneficial results of strength training (Latham et. al., 2004; Foldvari et. al., 2000; Granacher et. al., 2008), with noted additional benefits such as the ability to reduce the risk of osteoporosis, the signs of symptoms of chronic disease, improve sleep and reduce signs of depression (Seguin & Nelson, 2003).

Most of the benefits acknowledged in the literature highlight the increase in muscle strength and power due to the specific exercise regime. Therefore, it is important to explore training regimes, how they affect muscle strength and power and overall, how these factors play key roles in improving functional performance. A study conducted by Crockett et. al. (2013) examined the relationship between knee extensor strength/power and functional performance. Both concentric and eccentric strength and power were evaluated for 29 participants using an isokinetic dynamometer. Functional performance was tested using the 30 second sit-to-stand test. It was found that both concentric and eccentric strength and power measures were associated with higher performance onthe 30 second sit-to-stand test (Crockett et. al., 2013). A study conducted by Butcher et. al. (2012) investigated the relationship of functional performance results to leg muscle strength/power, as well as aerobic and anaerobic power in chronic obstructive pulmonary disease individuals. It was determined that the TUG test was highly correlated with isometric peak torque and the SCPT and the STS test were highly correlated to all strength variables (Butcher et. al., 2012). These studies highlight and demonstrate the importance of maintaining both muscle strength and power in order to maintain or improve functional performance across pathologies in an aging population.

Maintaining muscle strength and power can commonly be achieved through regular strength and power training in older adults (Bonder & Bello-Haas, 2018) yet traditional resistance training loading is limited based on the concentric phase of lifting. The maximum load and the force production during the concentric action of a contraction predicts and limits the load used during exercise. Greater force production of skeletal muscle during the eccentric phase of contractions in comparison to concentric have been documented (Maroto-Izquierdo et. al., 2017; Friedmann-Bette et. al., 2010). Therefore, the load determined concentrically results in sub-maximal activation and stimulation in the eccentric action and consequently limits the muscle hypertrophy, the increase in muscle strength and power and overall, the benefits of improving functional ability (Gault & Willems, 2013). Therefore, this highlights the importance of examining the benefits of eccentric training and the relationship it may have with maintaining or improving functional performance.

2.3.3 Eccentric Training, Eccentric Overload and Functional Performance

Eccentric actions are characterized as the lengthening of active muscles under tension, such that there is a stretch in the musculotendinous complex, most commonly described as a breaking force (Isner-Horobeti et. al., 2013; Gault & Willems, 2013; Hedayatpour & Falla, 2015). Commonly described as the motion when walking down a hill, eccentric actions involve muscle activation during lengthening movements (Hedayatpour & Falla, 2015). Therefore, eccentric training is an exercise regime that encompasses and focusses on repeating eccentric actions. The development of a flywheel device allows and promotes lower body eccentric training due to its ability to apply constant and unlimited resistance through all phases of squatting, eliminating the limitation previously described in weight training. As described by Reeves et. al., 2009, and Onambele et. al., 2008, the ability to apply maximum resistance through the whole range of motion shows similar or greater strength gains in comparison to traditional resistance training and also results in greater muscular adaptations. Tesch et. al., 2017 noted the development and practice of eccentric training in an elderly population combats sarcopenia more so than traditional resistance training. Additionally, the implementation of eccentric training improved balance, muscle force and muscle strength (Tesch et. al., 2017; Bruseghini et. al., 2015).

Although the concept of eccentric exercise is known, literature investigating eccentric training and functional ability using a flywheel in the older adult population is just commencing. A study conducted by Sanudo et. al., 2019 utilized a flywheel device to investigate the effects of flywheel training on mobility, postural stability and to compare power measurements to balance improvements in older adults. Participants trained using a flywheel device for a six-week period. The study found flywheel training to improve mobility, muscle power and balance in older adults (Sanudo et. al., 2019). A study conducted by LaStayo et al., 2003 examined the effect an eccentric training program elicited upon muscle size, strength, balance and fall risk on 21 subjects. It found that the eccentric training group displayed significant improvements in strength, balance and stair descent time (Lastayo et. al., 2003). Theodorou et. al., 2013 investigated whether "pure" eccentric exercise was transferable to functional ability. The pure eccentric action conducted during this study was descending a set of stairs. It was found that descending stairs was beneficial to older adults, and recommended activities that involve eccentric components for older adults to specifically increase muscle strength (Theodorou et. al., 2013). Different forms of eccentric training produce benefits regarding function as well. Moderate load eccentric exercise has been showed to increase function through reducing sarcopenia and increasing muscle strength and volume (Hoppeler, H., 2016). Further studies are required to investigate the optimal method to introduce eccentric training to a senior population as well as its protocols in order to confirm and optimize the benefits described by Sanudo et. al., 2019 (Isner-Horbeti et. al., 2013; Tesch et. al., 2017).

As described in literature, eccentric training encompasses multiple key benefits for a senior population. Eccentric actions produce greater skeletal muscle force with minimal energy expenditure (Insner-Horbeti et. al., 2013; Bonder & Bello-Hass, 2018; Gaul & Willems, 2013). It is theorized the greater force is likely due to a combination of multiple events. These physiological events include specific actions involved in cross-bridge cycling, as well as central activation strategies specific to eccentric actions. Both events seem to result in better muscular output (Insner-Horbeti et. al., 2013). This physiological advantage is attractive for an aging population as one could exert maximal force while exerting less energy, which is also beneficial for clinical settings (Hedayatpour & Falla, 2015; Vasquez-Morales et. al., 2013). The lower metabolic demand required for eccentric actions demonstrates metabolic efficiency, leading one to speculate that concentric and eccentric actions effect energy metabolism differently. It is believed that eccentric actions initiate a non-adenosine triphosphate (ATP) rupture of the actin-myosin cross-bridges, meaning less energy is required throughout the cross-bridge process. Evidence also indicates there is better synchronization of motor unit discharge through low recruitment of motor units and there is a unique neural strategy of motor control for eccentric actions (Insner-Horbeti et. al., 2013; Semmler et. al., 2002). The low oxygen demand may also be due to the high tension produced during eccentric action resulting in ischemia to the muscle (Hedayatpour & Falla, 2015). In addition, there is evidence that eccentric training has lower demand on the cardiovascular system (Hedayatpour & Falla, 2015). In one study, it was found that both cardiac output and heart rate (HR) are two times lower during eccentric actions than concentric, which held true for all age groups (Knuttgen & Klausen, 1971). Another benefit displayed by eccentric training is the increased adaptations due to repetitive eccentric actions. Illera-Dominguez et. al., 2018 had young, resistance -trained individuals use flywheel training for ten sessions. They reported the earliest onset of muscle hypertrophy to date. Literature has emphasized important alterations of the cytoskeleton and microlesions of muscle fibers occur following eccentric training (Insner-Horbeti et. al., 2013). Eccentric training causes more damage to initial and secondary muscle fibers, especially in older individuals. Increased damage may promote muscle repair through increased gene expression and hypertrophy, improving maximal strength (LaStayo et al., 1999; LaStayo et. al., 2000; Insner-Horbeti et. al., 2013; Illera-Dominguez et. al., 2018). This is key when assisting in functional performance (Bonder & Bello-Hass, 2018; Gault & Willems, 2013). Eccentric strength is preserved due to age-related adaptations, which is consistent across muscle groups. Bonder & Bello-Hass note that eccentric strength does not decline to a similar extent of isometric and concentric strength as one ages (Figure 2). Roig et. al., 2010 furthered this investigation claiming the preservation of eccentric strength is both biochemical and cellular as well as an accumulation of non-contractile material relating to muscle stiffness. This functional reserve of eccentric strength is important when implementing training regimes to increase functional ability and applying in clinical settings. Maintenance of eccentric strength in lower extremities maintains good stability, which is essential when aging (Wu et. al., 2002). Additional studies go above muscular adaptations and describe the cognitive improvements eccentric exercise induces (Fernandez-Gonzalo et. al., 2016).

All adaptations and benefits listed regarding eccentric training are summarized (Figure 3). This suggests its superior ability over traditional resistance training regarding increasing muscle strength and power as one ages, and over time, improving functional ability (Onambele et. al., 2008; Bruseghini et. al., 2015; Hortobagyi & DeVita, 2000; Vasquez-Morales et. al., 2013; Clark & Patten, 2013; LaStayo et. al., 2003). Understanding that eccentric training increases adaptations leading to increased muscular hypertrophy and muscle strength, a positive impact on functional performance is observed. By comprehending the speculated benefits of eccentric exercise and how it is related to functional performance, the question remains as to whether eccentric overload squatting is predictive of functional performance results. Eccentric overload is a concept that expands upon eccentric training. There is very little literature exploring the concept of eccentric overload in a senior population, the neuromuscular activation and benefits, with the results being controversial. Some literature finds benefits associated with eccentric training, while other studies have found that eccentric training is more or less equivalent to regular training (Dias et. al., 2015; Mueller et. al., 2009).

In all, eccentric training, in particular, greatly impacts muscle strength and power in older adults. Harnessing eccentric training is beneficial for a senior population, relating to functional performance and performing day-to-day activities. With the multiple benefits shown and understanding eccentric strength is preserved as one ages, eccentric training has a positive effect

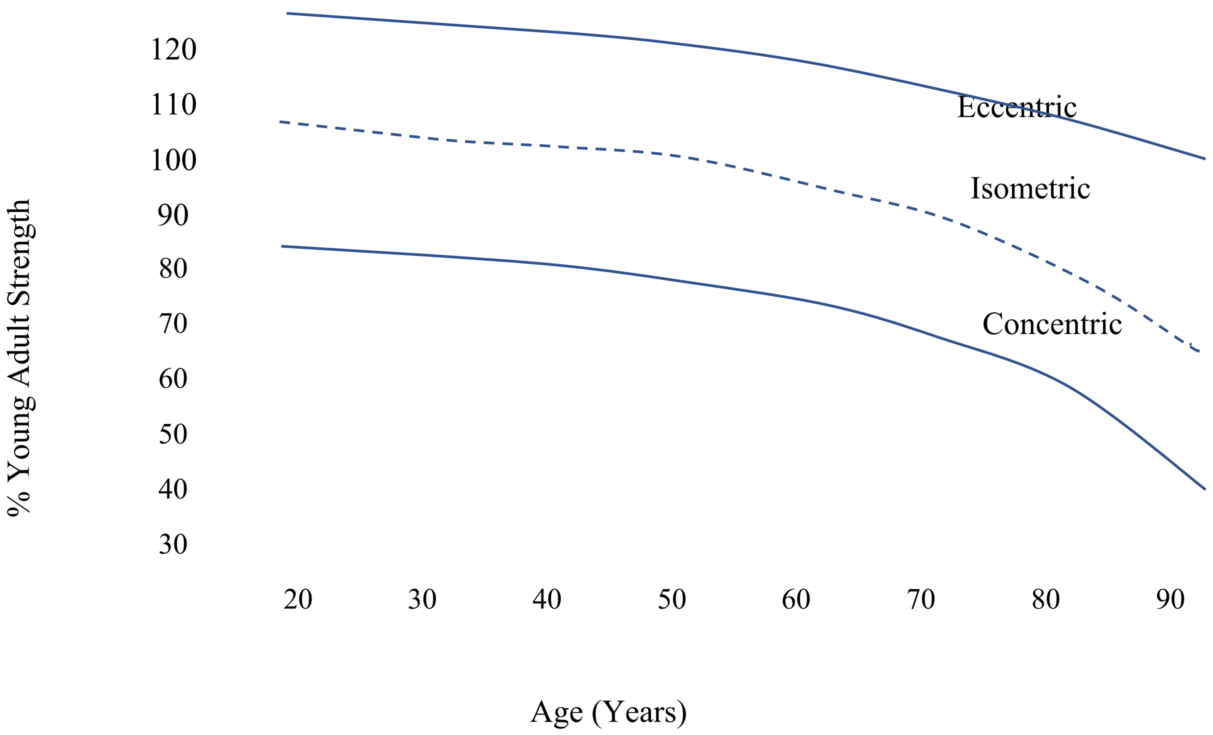


Figure 2: Adapted from Bonder & Bello-Hass, 2018, this figure displays the effects age has on maximal muscle strength. The shape and height of the curves display the various types of strength measured. As displayed, the type of strength that decreases the least with age is eccentric strength, followed by isometric and finally, concentric.

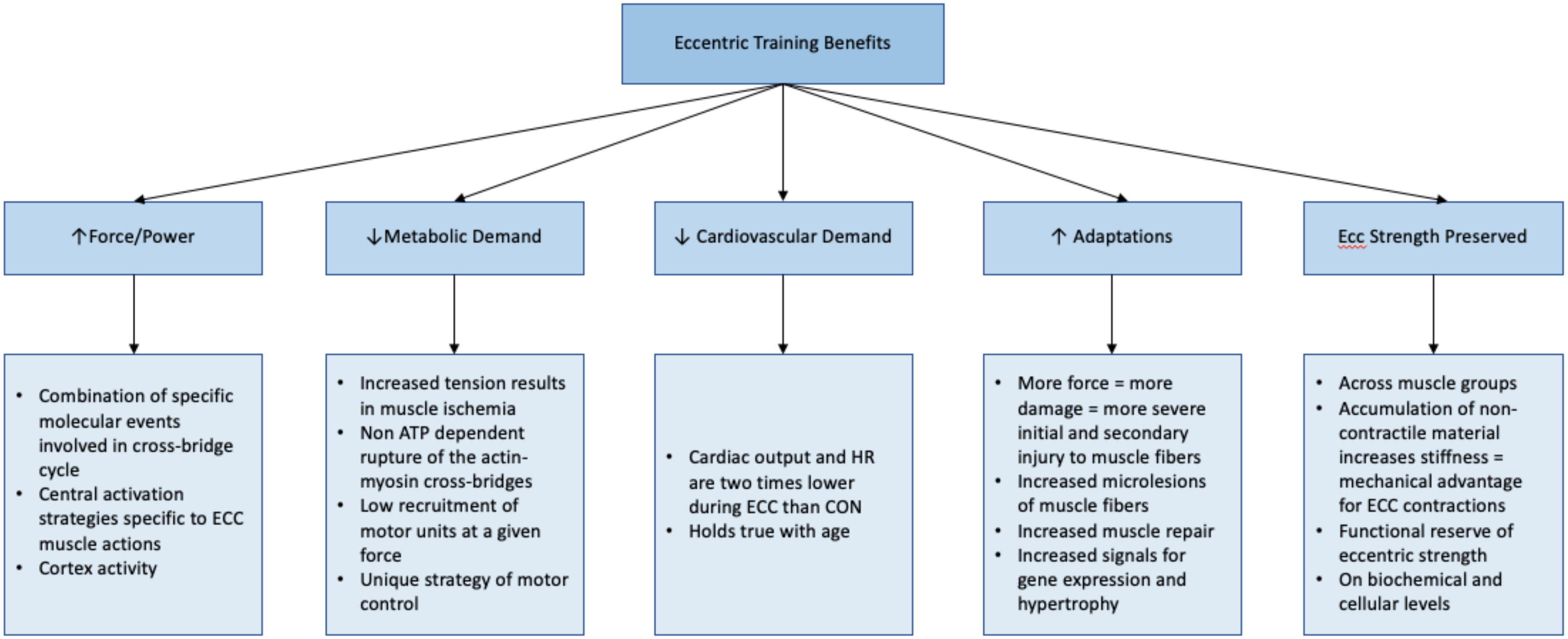


Figure 3: Summary of Eccentric Exercise Benefits on a senior population. The five key benefits of eccentric training on a senior population include increase force and power production, decreased metabolic demand (metabolic efficiency), decreased cardiovascular demand, increased muscular adaptations as well as the fact that eccentric strength is preserved. Information compiled from: Insner-Horbeti et. al., 2013; Bonder & Bello-Hass, 2018; Gaul & Willems, 2013; Hedayatpour & Falla, 2015; Vasquez-Morales et. al., 2013; Semmler et. al., 2002; Knuttgen & Klausen, 1971; LaStayo et al., 1999; LaStayo et. al., 2000; Roig et. al., 2010.

on functional performance outputs. Although benefits are observed through implementing this as a training regime, it still remains unclear if eccentric actions/training is predictive of functional performance. Eccentric training has a great association to benefits in older adults, but the question remains whether it physiologically predicts one's baseline functional activity. Overall, limited literature exists to examine the predictability of eccentric motions on functional performance and thus it requires further investigation.

2.4 Functional Performance Measures and Associations

2.4.1 How to Measure Functional Performance

Physical functional capacity and performance are factors that determine one's ability to conduct tasks for day-to-day life and therefore are important when considering predictive measures and promoting healthy aging. As mentioned previously, there are well-defined standard guidelines and protocols that efficiently and accurately measure one's functional performance (Bohannon R.W., 2006; Blackwood J., 2017; Westby et. al., 2015; Podsialdo & Richardson, 1991). These physical evaluations are simple, quick, easy to conduct and are great resources when determining and understanding functional ability which relate to an individual's muscle strength, power and how one's body has adapted during old age (Gautschi et. al., 2016; Bonder & Bello-Hass, 2018). The importance of conducting multiple functional tests has been identified through various literature, especially when one's goal is to obtain a comprehensive picture of an individual's functional ability (Park. S.H., 2018; Pereira et. al., 2019; Dias et. al., 2015). A study conducted by McPhee et. al., 2013 examined functional performance, strength, power, fatigue and neural activation through assessing participants utilizing multiple functional tests as well as physiological recordings in order to provide insight into normal, healthy aging. It was found that much of the decline observed in performance as one ages was largely linked to decreased muscle strength and the loss of muscle mass. It was therefore recommended that regular physical activity be maintained throughout the aging process. This study supports the concept of linking functional capacity with muscle strength and power as well as the importance of maintaining physical activity as a combative measure when one ages.

There are multiple tests to conduct when measuring functional performance. These tests include and are not limited to, the Time-Up-and-Go (TUG), the 6-minute walk test (6MWT), the stair-climb power test (SCPT), the five time sit-to-stand (FTSTS), the 10 meter walk test, gait speed (GS), the sock test, etc. (Benell et. al., 2011; Kubicki, A., 2014). Most of the evaluations measure lower body performance. Lower body performance is of utmost importance as lower limb strength is largely required for everyday activities and is predictive of fall incidences (Pereira et. al., 2019). These lower body evaluations assess gait, balance, strength, power and agility (Jones & Rikli, 2002). Lower body evaluations have demonstrated that muscle weakness, gait and balance deficits increase the risk of falls approximately 200% (Pizzigalli et. al., 2011). Therefore, with the objective to understand one's lower limb functional ability and the relationship to eccentric actions, three key functional tests have been identified of use for this study. Three tests were chosen based upon their ability to measure strength, power and function and are sufficient to gain an understanding into one's functional capabilities.

2.4.2 Time-up-and-go (TUG)

The timed-up-and-go (TUG) test is well established and commonly used test to evaluate functional performance and determine individuals who may be at risk of falling (Barry et. al., 2014; Lin et. al., 2017; Zarzenczny et. al., 2017). The TUG measures the duration, in seconds, it takes individuals to rise from an arm chair, walk three meters, turn to walk back to the chair and sit (Shumway-Cook et. al., 2000; Bohannon, RW., 2006). The time taken to complete the task described correlates to a level of functional capacity as it provides an assessment of walking ability, balance as well as strength (Shumway-Cook et. al., 2000; Zarzeczny et. al., 2017).

Results for this test have been normalized and stratified based upon age category and provide insight into one's level of function based upon how fast this task can be completed. Generally, those who complete the test in less than 10 seconds are said to be of normal functional capacity. If the TUG is completed by community dwelling adults, 14 seconds is the cut-off indicating a greater risk of fall incidences. From 14 seconds to 24 seconds indicates functional performance is adequate. If the test is completed between 24 to 30 seconds, mobility is classified as poor in which individuals usually require assistance in daily movement (University of Delaware; Saskatoon Falls Prevention 2005). Table 1 displays more details regarding age discrepancy and the TUG results.

The TUG test displays high intra-and inter-reliability as well as validity in a clinical setting (Gautschi et. al., 2016). This test has been utilized in many studies when assessing functional ability. When assessing the relationship of falling, balance and functional impairment, Kumar et. al., 2008 utilized the TUG test as one of many parameters. It was found

Age Group	Time in Seconds (95% Confidence Interval)	
60 – 69 years	8.1	(7.1 – 9.0)
70 – 79 years	9.2	(8.2 – 10.2)
80 – 89 years	11.3	(10.0 – 12.7)
Cut-off Values Predictive of Falls by		
Group	Time in Seconds	
Community Dwelling Frail Older Adults	> 14 associated with high fall risk	
Post-op hip fracture patients at time of discharge[3]	> 24 predictive of falls within 6 months after hip fracture	
Frail older adults	≥30 predictive of requiring assistive device for ambulation and being dependent in ADLs	

Table 1: TUG normative reference results stratified by age, along with the confidence intervals. Additionally, the time cut-off values are listed below, indicating how these relate to fall incidences (Saskatoon Falls Prevention, 2005; Bohannon R. W., 2006).

that the TUG test was highly correlated to fall incidences and overall, falling, balance and functional impairment were all clearly related. Steffen et. al., 2002 confirmed the high reliability of the TUG test in an elderly population. It was recommended that age-related data should be utilized when interpreting results, in support of the standards and normative values set forth (Table 1).

Although the TUG test is a tool regularly used when assesses functional ability, the importance of using more than one functional test cannot be stressed enough. When assessing the diagnostic ability of the TUG test, Schoene et. al., 2013 determined that the TUG test is predictive of falls in a less-healthy, lower functioning group of older adults and was not predictive of fall incidences in a high functioning group. This has been supported as Barry et. al., 2014 who suggests that the TUG test bears limited ability to predict falls in an older population. Kubicki, A., 2014 also suggests that the TUG test result is not a complete and accurate representation of an individual's mobility and that other tests, such as gait speed, provide better insight. Last, Steffen et al., 2002 who found the TUG test to be a reliable test also performed multiple functional tests when examining age and gender related test performance in the elderly community, confirming that more than one test is usually required. Overall, the TUG test is a commonly used evaluation of functional performance and displays high intra and inter-reliability and validity when measuring function, but the test does have limitations. Hence, more than one functional test should be conducted in order to attain a complete understanding of functional mobility.

2.4.3 Five time sit-to-stand test (FTSTS)

The FTSTS test is straightforward to conduct and relates to the activation of lower limb muscles, muscle strength, power and balance (Bohannon R. W., 2019). Not only is this activity related to muscle strength and power, it is a task that is conducted by individuals day-to-day when maintaining functional capacity and independence (Wallmann et. al., 2013). In this task, individuals start seated in a chair with their arms folded/crossed over their chest. When instructed, the individual will rise and sit back down as fast as they can, for a total of 5 repetitions (Bohannon et. al., 2010; Wallman et. al., 2013; Blackwood, J., 2017). Timed results of this test have been normalized and stratified based upon age and are useful when conceptualizing mobility, or difficulties functioning (Jordre et. al., 2013). Individuals who are below 70 years of age, 80 years of age and 90 years of age and who take 11.4 seconds, 12.6

seconds and 14.8 seconds respectively, to complete this test are deemed low functioning with poor mobility (Bohannon et. al., 2006).

The FTSST test has shown high reliability and validity in multiple age groups as well as across multiple pathologies (Blackwood, J., 2017; Wang et. al., 2011; Jordre et. al., 2013; Wallmann et. al., 2013). Due to the reliability and validity of this test, it has been utilized in multiple studies investigating functional performance. Bohannon et. al., 2010 aimed to produce results of the FTSST test across age groups as well as determine the relationship between this functional test and knee extension strength, gender, body weight, and age. Both age and knee extensor strength were greatly correlated to the results of the FTSST. Manorangsan et. al., 2015 displayed different FTSTS test results from those classified as fallers and those classified as non-fallers, demonstrating the FTSTS capability of measuring various levels of functional performance. It has also been demonstrated that active older individuals who partake in regular physical activity in comparison to non-active older adults display better results in the FTSST test (Jordre et. al., 2013), emphasizing the correlation between muscle strength and functional ability. These studies demonstrate the effectiveness of the FTSST test when evaluating function across ages.

Although many studies have displayed high reliability and validity of the FTSST test, this test is not usually the singular method used in studies. When the sit-to-stand test was used and evaluated by McCarthy et. al., 2004, it was found that variance in the sit-to-stand motion was still unexplained. Such results highlight the importance of using other parameters when evaluating functional performance. Additionally, little investigation into concentric and eccentric strength relations to this test has been conducted. Wretenberg et. al., 1994 examined the power outputs and work of difference muscle groups during a rising motion. Although this provided insight into the physiology behind the standing motion, further investigation is required to investigate muscle groups strength and power and their relation and predictability of the FTSTS test.

2.4.4 Stair Climb Power Test (SCPT)

Stair climbing is an essential task of everyday life which is dependent upon multiple physical factors that are critical for maintaining one’s independence (Martins, P. 2015; Hellmers et. al., 2018; Martha et. al., 2017). The SCPT is a measure of function, muscle strength, muscle power, balance and agility (Westby et. al., 2015; Bennell et. al., 2011). The SCPT is an easy task to conduct, is reproducible, takes little time, and requires little equipment (Martins, P., 2015). For this task, participants are timed for the duration required to ascend 10 stairs, instructed to not use the hand rail, and to take one stair at a time with a stair height approximately between 16-20centimeters (Westby et. al., 2015). Timed results of the SCPT have been normalized and stratified by age through other literature and are used as a reference. The average speed required when climbing approximately 8-10 steps is between 1.3steps/second and 1.8steps/second (Martins, P., 2015; Hinman et. al., 2014). Due to the movement the SCPT encompasses, these results can provide great insight into one's level of function and lower body strength (Westby et. al., 2015; Bean et. al., 2007).

The SCPT has displayed good reliability and validity throughout literature and many adaptations to this test have been produced when accounting for various pathologies (Westby et. al., 2015; Bennell et. al., 2011; Bean et, al., 2007; Roig et. al., 2010). Collins et. al., 2008 compared the results of the SCPT to other functional tests including the 6-minute walk test, chair rise test, gait speed and a self-questionnaire. A total of 105 individuals participated in this study and it was found that the SCPT is a valid measurement of function and correlated highly with gait speed (Collins et. al., 2008). Lin, YC et. al., 2001 tested the reliability of many functional tests, including the SCPT. It was determined that this is a reliable test when evaluating function in a senior population (Lin, YC. et. al., 2001).

The movement and muscle requirements for the SCPT make it one of the most important functional evaluations when assessing muscle power (Martins, P., 2015; Bean et. al., 2007). The SCPT is associated with complex evaluations of power deficits and is highly associated with mobility performance (Bean et, al., 2007). This evaluation requires greater range of motion and muscle strength than other daily tasks and therefore can demonstrate functional difficulties more readily than other functional tests (Nightingale et. al., 2014). Through understanding the importance of the SCPT, it should be included when evaluating lower limb power and overall functional ability.

It is critical when assessing functional performance to utilize more than one functional test. The TUG test and the FTSTS test are critical when understanding lower limb function and strength, both displaying high reliability and validity. Therefore, the SCPT, TUG test and FTSTS test when applied in combination should provide a sufficient profile of an individual's lower body strength, power, agility, balance and overall function. When examining eccentric loading as a prediction of functional performance, these tests require further investigation as there is a limited amount of literature that examines the effects of specific eccentric measurements, its association and predictability of function. Since these tests are well-established, commonly used, highly reliable and valid, they should provide accurate determination if eccentric squat loading is predictable of performance in older individuals.

2.5 Measures of Muscle Strength and Power

In order to determine the association and predictability of eccentric squat loading on functional performance, certain measurement comparisons must be made. Muscle strength and power are key determinants of functional performance and are parameters that can be measured both concentrically and eccentrically (Bonder & Bello-Hass, 2018; Pizzigalli et. al., 2011; Park et. al., 2006). Additionally, muscle strength and power can be targeted as the overarching theme of all adaptations through aging therefore highlighting the importance of these evaluations (Chodzko-Zajko et. al., 2009). Through the comparisons of muscle strength and power determined both concentrically and eccentrically as well as the results of the functional tests listed, the TUG, the FTSTS and the SCPT, one should be able to determine correlations, predictability or the absence of associations. The variability in how these measurements are made, either through single joint measurements or whole-body measurements needs to be explored further in order to understand how these parameters can be appropriately compared.

2.5.1 Muscle Strength

Muscle strength is defined as the ability of a muscle group to generate a force/torque against a resistance at a particular joint in a single effort (Brown & Weir, 2001; Bonder & Bello-Haas, 2018; Komi, P., 2008). Maximum muscular strength of individuals is observed during the second or third decade of one’s life and then progressively declines. (Bonder & Bello-Hass, 2018). Muscle strength is critical for day-to-day life, functional performance and preventing falling (Bonder & Bello-Hass, 2018; Hairi et. al., 2010; Pizzigalli et. al., 2011; Miszko et. al., 2003). Lower limb strength in particular is essential regarding physical limitations (Park et. al., 2006; Pizzigalli et. al., 2011). When examining 1705 community dwelling men, Hairi et. al., 2010 determined that muscle strength was a key measure in predicting physical disabilities and poor functional performance. Although strength is lost through aging, eccentric strength declines at a lesser rate than both isometric and concentric strength making eccentric strength important to focus upon when evaluating strength in individuals as we age as well as when predicting and assessing functional ability, understanding how closely strength relates to function (Bonder & Bello-Hass, 2018).

Evaluating and quantifying muscle strength can be obtained through multiple methods including manual techniques, functional techniques and instrumentation (Bonder & Bello-Haas, 2018). Measuring muscle strength through manual techniques requires evidence of contraction, opposition of gravity, as well as opposition of manual resistance (Clarkson, H.M., 2000). Grading is completed on a scale from 0 through 5, with 5 being the ability to resist the greatest showing greater muscular strength (Clarkson, H.M., 2000). Functional techniques include functional test such as those listed previously, the TUG, FTSTS and SCPT. Instrumentation techniques include evaluation of muscle strength by an isokinetic dynamometer. An isokinetic dynamometer is a system used to test and quantify joint performance, muscle function and assist in the diagnosis and treatment of various pathologies (Computer Sports Medicine, 2006; Alvares, J. et. al., 2015). It is noted by Bonder & Bello-Haas 2018, that evaluation of muscle strength using an isokinetic dynamometer is of higher quality than other methods due to the ability to control speeds at which strength is evaluated, giving the dynamometer the capability of more appropriately assessing age-related strength changes. The dynamometer is a sophisticated method of evaluating muscle strength in comparison to other methods and has been established as the “gold standard”. Strength can be measured both concentrically and eccentrically using this method (Martin, H.J., et. al., 2006; Hansen et. al., 2015; Bonder & Bello-Haas, 2018).

Recent methods have been developed that measure muscle strength both concentrically and eccentrically. These new methods include flywheel devices which may have the potential to replace a dynamometer as a more appropriate measure. Very little literature explores the capabilities of a flywheel device when measuring muscle strength in comparison to an isokinetic dynamometer. Therefore, when assessing muscle strength in a clinical setting and for predicting functional ability, both an isokinetic dynamometer and a flywheel device will be used.

2.5.2 Muscle Power

Muscle power and muscle strength are related but are separate characteristics when assessing an individual’s physical state (Bean et. al., 2002; Bonder & Bello-Haas, 2018). Muscle power is the capability of generating force with velocity against resistance and is calculated as the muscle force in one effort, multiplied by the velocity of the movement (Bonder & Bello-Haas, 2018; Bean et. al., 2002). It is a combination of the force produced (strength) and the speed during the motion requiring coordination and timing. Similar to muscle strength, muscle power is dependent upon a multitude of factors including the number and the diameter of myofibrils, muscle fiber type, coordination of neurological elements, sarcopenia, age, and gender (Bonder & Bello-Haas, 2018). Literature indicates muscle power declines at a greater rate than muscle strength in aging individuals (Bonder & Bello-Hass, 2018; Foldvari et. al., 2000). Muscle power has been speculated to be a greater factor in the predictability of functional performance in comparison to strength (Evans, W., 2000; Skelton et. al., 2002; Henwood et. al., 2008; Reid & Fielding, 2012). Bassey et. al., 1992 found muscle power to be more greatly associated with stair climbing, rising from a chair and walking than muscle strength. Similar to strength, eccentric muscle power decreases less in comparison to concentric muscle power as one ages (Bonder & Bello-Haas, 2018).

Assessing muscle power in practice is complicated in comparison to muscle strength due to the measure of both forces produced and speed of the contraction (Bahat et. al., 2021). Although guidelines are established when evaluating both muscle force and speed of contraction, an isokinetic dynamometer is greatly advantageous to determine such evaluations. A predetermined speed can be set, controlled, and used making evaluation of muscle power much easier and reliable than other methods (Bonder & Bello-Haas, 2018). A flywheel device, such as the kBox, is capable of producing power measurements both concentrically and eccentrically and is a method used during this experiment. Through understanding the physiological importance of muscle power and its relation to functional performance, this will be one key factor assessed in this study. Similarly to muscle strength, muscle power will be evaluated through the use of an isokinetic dynamometer as well as a flywheel device.

2.5.3 Rate of Torque Development (RTD)

The RTD is described as the action of muscle performance that involves producing force rapidly during a voluntary contraction critical for physical function as one ages (Osawa et. al., 2018; Morel et. al., 2015; Maffiulett et. al., 2016). The RTD, which is identified by a torque-time curve, decreases as one ages (Osawa et. al., 2018; Kitagawa, T., 2014). The importance of including RTD as an assessment component is this parameter accounts for the motion of rapid force production for movements such as catching one's self before a fall, jumping, or brisk walking (Osawa et. al., 2018). Assessing the time required for one to reach peak torque or to develop torque rapidly is crucial for aging as this can predict one's capability of change of direction movements as well as fall prevention (Bento et. al., 2010; Kitagawa, T., 2014; Driessche et. al., 2018). RTD is an effective measurement not only across age ranges but across comorbidities (Osawa et. al., 2018; Moreau et. al. 2012; Pohl et. al. 2002). In a study conducted by Kline et. al., 2019, RTD was assessed and related to other tests conducted for patients after knee arthroplasty. It was found that RTD is a key factor for rehabilitation purposes and training programs should focus around such parameter improvements (Kline et. al., 2019). Although peak force (strength) is a great indicator of physical performance, the speed of force development may be an independent contributing factor to predicting and assessing function in seniors (Osawa et. al., 2018; Driessche et. al., 2018). A study conducted by Driessche et. al., 2018 examined age related declines in peak torque as well as RTD. It concluded that the differences observed in RTD exceeded age-related differences in peak power, emphasizing the loss of ability to generate power as one ages and the decline in physical function in addition to the importance of using RTD as an assessment measure (Driessche et. al., 2018). RTD is dependent upon multiple physiological factors including muscle fiber type muscle composition, muscle tendon stiffness, muscle activation, muscle cross-sectional area, and muscle unit recruitment (Maffiulett et. al., 2016). Eccentric training has demonstrated to improve RTD (Oliveira et. al., 2016), providing additional evidence for the benefits associated with eccentric training implementation in a senior population.

There are key differences between muscle power and RTD. As outlined by Osawa et. al. 2018, muscle power assessments usually produce average values, involve complex machinery and evaluation techniques and may be difficult to properly assess in an aging population for safety concerns. RTD is a different measure as it provides quick evaluation of peak outputs and can be measured isometrically which is a safer method for a senior population (Osawa et. al., 2018; Maffiulett et. al., 2016). When assessing strength of an individual on a dynamometer through isometric single joint contractions, one can also assess the rate at which this is done, therefore measuring RTD simultaneously because RTD is an expression of strength. One disadvantage of measuring RTD during isometric contractions is the decreased reliability in comparison to other parameters (Maffiulett et. al., 2016). Overall, RTD is an important parameter to include when assessing functional ability.

2.5.4 Single Joint Measures Compared to Multi-Joint Measures

When examining human movement, one can divide such measurements into various parameters such as single joint measures or multi-joint measures (Flanagan & Salem, 2005). It is common during single joint measures to sum joint kinetics to obtain a multi-joint evaluation. Single joint measures are commonly conducted when specific muscles are of interest, using a dynamometer to isolate areas. Single joint measure evaluations are often conducted when assessing muscle strength, power, and function through the use of a dynamometer. Flanagan & Salem, 2005 found that the summation of 6 various lower limb measurements were a valid form of assessment of lower limb function. Schulz et. al., 2008 demonstrated that single joint kinematics is highly associated with the clinical step test length, which is predictive of function. Hayden et. al., 2017 used a dynamometer to perform concentric isokinetic contractions to assess if single-joint power output displays similar age-related declines of functional lower body movement. Although the dynamometer single-joint evaluation may produce weaker outputs, results were consistent with age declines.

Although single-joint testing is useful in experiments interested in single muscle group evaluations and functional evaluation, it is noted that single joint evaluations may not be completely appropriate measures for functional performance due to the multiple joint movement required for these motions. Additionally, using single-joint kinematic evaluation limits the scope of evaluation and possible treatments in a clinical setting (van den Bogert et. al., 2013). Difficulty arises when assessing multi-joint motions due to limited instrumentation capable of doing so. Taraldsen et. al., 2011 examined the validity of small body-worn accelerometers in comparison to video evaluation assessing multi-joint movement and overall function in a frail population. This form of instrumentation was found to be a valid form of measure when assessing walking in the frail. Although many other forms of accelerometers are available, these are only capable of limited outputs (Zeng & Zhao, 2011). Therefore, instrumentation that assesses multi-joint parameters such as strength and power need to be investigated further. The flywheel device that will be examined in this study is an alternative to this and is explored later.

Both single-joint and multi-joint actions can also be examined based upon training regimes, their contributions to muscle strength and power, as well as their effect on functional performance. As described by Gentil et. al., 2017, resistance training can be either single-joint or multi-joint. Single-joint training utilizes exercises that single out a particular muscle group of interest, such as a leg extension. Whole-body movement use multi-joint movements incorporating many muscle groups, such as a squatting motion. Studies have examined the impact of adding single-joint training to a multi-joint resistance training regime on physiological outcomes such as muscle thickness and peak torque produced (Gentil et. al., 2013; Franca et. al., 2015). This addition is examined because it is speculated that adding single-joint movements to a training program may optimize gains in both muscle strength and size (Gentil et. al., 2017). Gentil et. al. 2013 examined the addition of single-joint movements to a training program in untrained young males whereas Franca et. al., 2015 investigated the addition of single-joint movements to a training program in young, strength-trained males. For each population, it was found that the addition of single-joint training to a multi-joint training regime resulted in no significant difference, suggesting a multi-joint resistant training program to be sufficient (Gentil et. al., 2013; Franca et. al., 2015). Therefore, single-joint exercise itself does not result in greater effector on gains in muscle strength, power or size in comparison to multi-joint training.

Multi-joint training is more reflective of specific activities through daily life (Schoenfeld & Contreras, 2012). The adaptations and gains in muscle strength and power through multi-joint resistance training are evident. In a group of young men, Tanimoto et. al., 2008 examined the effects of multi-joint low resistance training on both muscle size and muscle strength. After a period of 13 weeks, it was found that both multi-joint low resistance and whole-body high resistance training resulted in significant increases in muscle strength and muscle size (Tanimoto et. al., 2008). A limitation of multi-joint exercises is the possibility of muscle imbalances through the selected activation of muscle groups, dependent upon the exercise being conducted (Schoenfeld & Contreras, 2012). This has been demonstrated through recording electromyographic data, which displayed that hamstring activation through the motion of a squat was less than during isolated exercises (Schoenfeld & Contreras, 2012). This limitation may be overcome by implementing eccentric overload training protocols through the use of flywheel devices. The constant resistance applied through all phases of a contraction may elicit greater muscle activation, resulting in greater hypertrophy, adaptations, and overall an increase in strength, power and functional ability (Norrbrand et. al. 2008, Reeves et. al., 2009, and Onambele et. al., 2008). Recognizing that eccentric strength is preserved as one ages, the importance of eccentric strength for daily activities, and the multiple benefits eccentric training has for a senior population, further investigation into this form of multi-joint evaluation is required.

2.6 Physiological Measures

When gaining insight into the predictability of eccentric squat loading on functional performance through various equipment, physiological measures may provide critical insight into the similarities and/or differences these methods produce. Information gained through physiological measures can assist in understanding an individual’s fitness level, physical capabilities as well as overall health (Bonder & Bello-Haas, 2018). Physiological measures differ from person to person and within different evaluation methods (Yoon, 2002). The following sections explore two physiological measures, the information gathered, and how this information can be used to compare and contrast various exercise evaluation modalities.

2.6.1 Electromyography (EMG)

EMG is a technique used to measure action potentials of motor units in skeletal muscle as a collective electrical signal from the tissue of interest (Raez et. al., 2006; Halaki & Ginn, 2012). EMG measures assist in understanding the contribution of force of single muscles in a biomedical viewpoint and represents neuromuscular activities (De Luca, G. 2003; Raez et. al., 2006). EMG readings are useful when examining patterns of muscle activation, either between individuals or over time. These readings provide insight into parameters such as force, activation time, fatigue, co-activation, pattern identification, and relative amount of contribution (De Luca, G. 2003). Invasive and non-invasive are the two main methods of EMG readings, also known as surface EMG (sEMG). sEMG is a method that detects motor unit action potentials (MUAP), displaying skeletal muscle response to neural stimulation (Raez et. al., 2006). sEMG provides insight into muscle activation at rest and during contractions. Electrodes are attached to the skin surface above muscles of interest and work as amplifiers of the electrical signals detected (Halaki & Ginn, 2012). This signal is variable upon factors such as electrode configuration, perspiration and temperature, electrode placement, muscle fiber type, microcirculation, muscle fiber diameter, distance between active fibers, tissue between surface of muscle and electrode and skin preparation and impedance (Halaki & Ginn, 2012; De Luca, G., 2003).

The external factors including electrode configuration, electrode placement and skin preparation can be controlled for reducing noise and distortion of the sEMG signal and increasing the accuracy of readings (Raez et. al., 2006). For the current study, lower limb strength and power assessments involve the actions of knee extensions, squatting, and the movement required for the TUG, FTSTS and SCPT tests. Therefore, the main muscles of interest include the vastus lateralis (VL), vastus medialis (VM), and the rectus femoris (RF), (Norrbrand et. al., 2010). A common, well-established body of knowledge regarding sEMG usage was produced by SENIAM (surface EMG for non-invasive assessment of muscles, 1999) and guides electrode placement for each skeletal muscle of interest. A figure regarding the measurements and placements can be viewed (Figure 4).

Different activities evoke various neural stimulation, motor recruitment and therefore produce different sEMG outputs. Eccentric actions and sEMG readings have produced controversial and conflicting findings in previous literature. When comparing a flywheel exercise and traditional resistance training, higher sEMG activity was noted in the flywheel group (Norrbrand et. al., 2010). This investigation attributes the greater sEMG readings and muscle activation to the iso-inertial load technique utilized by the flywheel device (Norrbrand et. al, 2010). In contrast, other studies have noted lesser sEMG activity for eccentric actions than concentric actions. When comparing concentric and eccentric exercise through cycling and trunk extension exercises, it was found that the concentric sEMG readings were double that of the eccentric readings (Ebenbichler et. al., 2017). As summarized by the Institute of Sports Medicine Copenhagen, University of Denmark, there are several reasons sEMG signals are less eccentrically than concentrically (Aagaard, P., 2016). Pre-loaded tension in tendons results in less muscular demand, leading to smaller sEMG readings. Additionally, distinct neural activation patterns exist in the brain for both eccentric and concentric actions and within the central nervous system, post-synaptic and pre-synaptic sites of inhibition exist for eccentric action pathways. Last, the metabolic efficiency displayed through eccentric actions for greater force production may influence the motor units recruited (Aagaard, P., 2016). The concept of various neural pathways and adaptations between muscle actions has also been noted in other studies examining both concentric and eccentric sEMG outputs (Guilhem et. al., 2011; Ebenbichler et. al., 2017). These factors, in combination, result in a smaller EMG reading during eccentric actions in comparison to concentric actions.

Through the understanding and use of the sEMG technique described, sEMG proves to serve as a great tool when comparing muscle activation, force, and neural drive between tasks, people, and time. This is useful when comparing dynamometer outputs, flywheel outputs, as well as when comparing activation amplitudes and patters within functional tests. This provides insight to understanding the physiological similarities and differences between modalities. Through the rectification, integration and normalization methods, the sEMG signal can be used to analyze different patterns across exercise regimes. Due to the controversial information regarding sEMG and eccentric actions, further investigation is required into the physiology behind and between various actions. This can be achieved through all tests including the concentric, eccentric, and isometric dynamometer tests, the flywheel device, as well as through functional tests.

2.6.2 Muscle Oxygenation (MO)

MO, also known as muscle oxygen saturation, is the balance between the rate of tissue perfusion and oxygen uptake by skeletal muscle tissue (Boron & Boulpaep, 2012). The rate at which oxygen is delivered to muscles and the rate at which it is consumed determine the rate of muscle oxygenation. As metabolic demands of cells increase through exercise, there is an increase in the cardiac output to ensure adequate oxygenated blood reaches the tissues as well as increased breathing/ventilation to ensure arterial blood is sufficiently saturated (Boron & Boulpaep, 2012). Muscle oxygenation can be modified by exercise through directing high perfusion to tissues with increased metabolic demand and decrease perfusion at vascular beds. Initially during exercise, the extraction of oxygen by skeletal muscle increases. Although the body has established methods of increasing muscle oxygenation, there are limits within extraction and delivery (Boron & Boulpaep, 2012). The detection and measurement of MO can provide insight into the metabolic activity during specific forms of exercise (Boron & Boulpaep, 2012). Therefore, one can detect the MO differences and similarities between methods measuring muscle strength and power and determine if each are predictive of functional performance.

A common method to measure MO at rest and during exercise is through near-infrared spectroscopy (NIRS) (Kennedy et. al., 2006). NIRS is an advantageous form of measurement due to its reliability, but also due to advances it is a non-invasive method well suited for microcirculation of muscle tissues (Kennedy et. al., 2006; Perrey & Ferrari, 2018). The NIRS equipment can be viewed (Figure 4). The different oxygenation levels of blood absorb as well as reflect NIRS light at various spectrums and are measured by the detector and muscle oxygenation is determined based upon the modified Beer-Lambert Law (Kennedy et. al., 2006;

Figure 4: The NIRO-200X manufactured by Hamatsu Photonics.   The light emitting and detecting electrodes have been highlighted. This is the NIRS equipment used in detecting muscle oxygenation (Hamamatsu Photonics K. K., 2018).

Scheeren et. al., 2012). The tissue oxygenation index (TOI) is a parameter provided through NIRS that is of great use as it represents the dynamic balance of oxygen supply by the muscle microcirculation and the oxygen demand by the muscle of interest (Muthalib et. al., 2010). NIRS measurements can be affected by microcirculation, oxygen use, exercise regime, muscle fiber type and placement of electrode on the muscle of interest (Kennedy et. al., 2006; Spires et. al., 2011; Boron & Boulpaep et. al., 2012). Microcirculation variances due to specific blood flow restriction (BFR) is important to consider, especially during eccentric actions, when assessing various exercise evaluations and has been associated with metabolic stress, inducing muscle hypertrophy and increasing muscle strength (Reis et. al., 2019; Lauver et. al., 2017).

The type of evaluation being conducted during testing will contain both concentric and eccentric actions through the use of a dynamometer and flywheel device when measuring muscle strength and power. There is lower metabolic demand for eccentric actions in comparison to concentric actions (Gault & Willems, 2013). When comparing eccentric cycling on an ergometer with concentric cycling, it was found eccentric oxygen demand was one-sixth of that for concentric (Bigland-Ritchie & Woods, 1976). Similar evidence was demonstrated by Gault & Willems, 2013 when comparing downhill walking (eccentric) to level walking (concentric dominant). Trends for eccentric aerobic exercise include reduced cardiac demand as well as reduced metabolic demand (Gault & Willems, 2013). Most studies examining eccentric actions and concentric actions regarding metabolism have focused upon aerobic exercise. For the current study being conducted, the method examined involves both concentric and eccentric actions but is not aerobic activity. Although different, similar metabolic efficient demands through eccentric actions are expected to be observed during evaluation in comparison to concentric and isometric.

MO is an important physiological factor to examine when comparing different evaluation modalities because it provides insight into the metabolic demand/requirements of each method. NIRS is a reliable and valid method for measuring MO of tissues and is advantageous due to its non-invasive nature. Placement of the electrode when recording MO will be standardized due to the noted variability in measures upon differential muscular regions. When comparing the dynamometer and flywheel device, similar MO patterns regarding eccentric contractions are expected as well as BFR will be considered of importance when examining the percentage of TOI.

2.7 Isokinetic HUMAC NORM Dynamometer and the kBox 4 Flywheel

2.7.1 Isokinetic HUMAN NORM Dynamometer

The isokinetic HUMAN NORM dynamometer is a system used to test and quantify muscle function, joint performance, and diagnose and treat those with musculoskeletal pathologies (Computer Sports Medicine, 2006; Alvares, J. et. al., 2015). The isokinetic dynamometer is a single-chair set up (Figure 5) that allows for multiple tests for various muscles of interest, while controlling resistance, angular velocity, and therefore determining range of motion (ROM) (Computer Sports Medicine, 2006; Habets et. al., 2018). Assessment of muscle function and performance can be conducted through isometric contractions, concentric actions and eccentric actions. This is useful when evaluating parameters such as strength and power for various components of a contraction. Isokinetic dynamometer evaluations of muscle strength are highly valid, supported through 20 years of clinical research (Habets et. al. 2018; Computer Sports Medicine, 2006). The use of a dynamometer is effective, reliable, reproducible and a safe method of muscle strength and power evaluation across ages and pathologies (Drouin et. al., 2004; Webber & Porter, 2010; Habets et. al., 2018). The benefits of dynamometer evaluation include the most efficient use of muscle output, reduced chance of overload injury, adjustments of evaluations to those experiencing pain or muscle fatigue, a full range of speed for testing various exercises which can single out evaluation of fast-twitch fibers or slow-twitch fibers, and decreased compression on joints (Computer Sports Medicine, 2006; Alvares, J., et. al., 2015).

2.7.2 Typical Uses

Isokinetic dynamometers can be used in clinical evaluations, rehabilitation programs, and treatment plans (Computer Sports Medicine, 2006; Habets et. al., 2018). One of the major uses of an isokinetic dynamometer is for research purposes, displaying reliability and validity (Alvares, J., et. al., 2015; Habets etl al., 2018). Major muscle groups commonly evaluated using a dynamometer are shoulders, knees, elbows, wrists, hips, ankles and back. Isokinetic dynamometry is advantageous in clinical and rehabilitation situations due to its safety and reproducibility of results through well-established testing protocols (Cvjetkovic et. al., 2015). The technology employed in an isokinetic dynamometer, it can provide objective, real time quantification of muscle strength, power and endurance which provides a muscular profile as well as track individuals progress through rehabilitation programs (Computer Sports Medicine, 2006). Isokinetic dynamometers are commonly used in rehabilitation programs for athletes

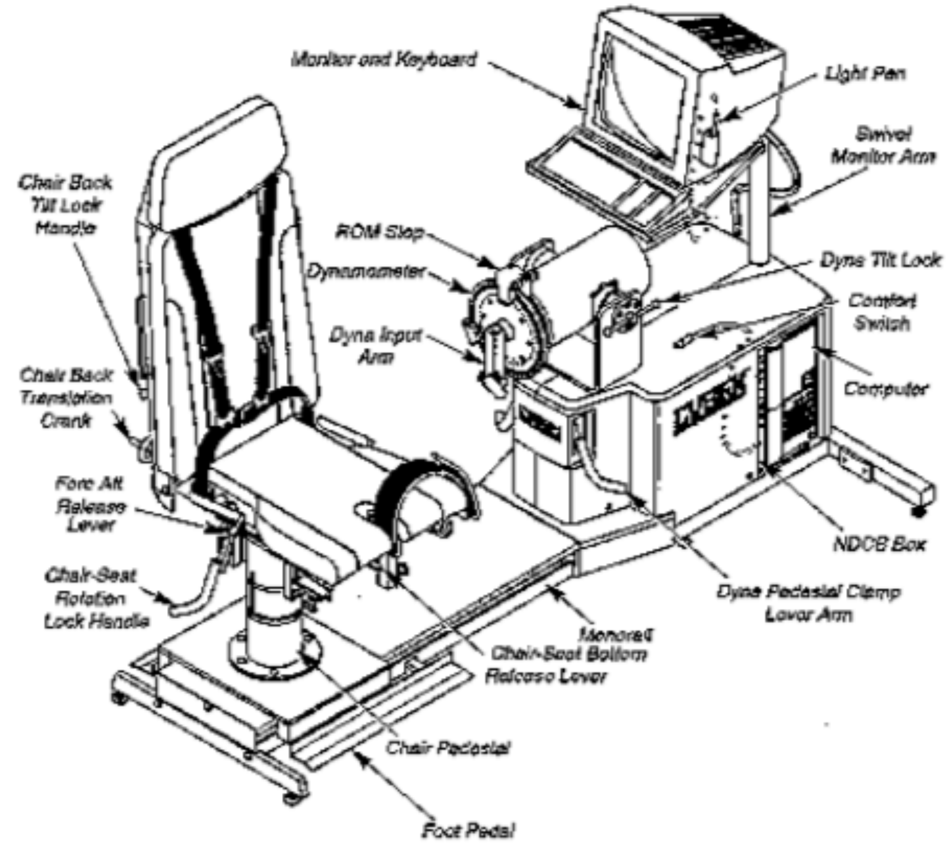


Figure 5: The HUMAC NORM Dynamometer system and its mechanical components (Computer Sports Medicine, 2006).

and young, strength-trained individuals. O’Malley et. al., 2018 utilized an isokinetic dynamometer to assess progress of athletes through a rehabilitation program after an anterior cruciate ligament reconstruction. This study provided a prescribed peak torque in muscle strength that athletes should aim to reach to ensure appropriate rehabilitation progress is made (O’Malley et. al., 2018). Isokinetic dynamometry has also been utilized in rehabilitation of patients who have a diagnosis of multiple sclerosis, stroke and other comorbidities (Hameau et. al., 2018; Coroian et. al., 2018). Due to the benefits listed and the implications of dynamometer measures, this form of evaluation is useful when assessing functional performance in an older population.

2.7.3 Measures of Muscle Strength, Power, and Functional Performance

The use of an isokinetic dynamometer to measure muscle strength and power enables the quantification and evaluation of functional status in older adults (Hartmann et. al., 2009). Due to the noted importance of lower limb strength and power relation to functional performance, an isokinetic dynamometer can be utilized in assessing these parameters and therefore, be predictive of functional performance. Many studies have utilized the knee extension movement assessed by a dynamometer to evaluate lower limb strength and power in the elderly (Alonso et. al., 2018; Samuel, D., et. al., 2013; Buckley C. et. a., 2017; Chen L. et. a., 2013). In a study conducted by Misic, et. al., 2007, an isokinetic dynamometer was one of many assessments conducted when determining predictors of functional performance in the elderly. It was determined that lower body (leg) muscle quality, meaning strength, power and mass, were the parameters most greatly associated with functional performance (Misic et. al., 2007). This study highlights the use of a dynamometer in predicting functionally, and also ties in the concept of maintaining function. In another study conducted by Ahmadiahangar et. al., 2018, an isokinetic dynamometer was utilized to assess muscle strength of the quadricep muscles through the motion of a knee extension to see if muscle strength was predictive of falls. It was found that quadricep strength is a great predictor of falls, indicating the crucial aspect of maintaining lower body strength as one ages (Ahmadiahangar, A., et. al., 2018). When assessing peak power and the rate of power development using a dynamometer, maximal isotonic contractions of knee extensions against various loads were utilized (Drissche et. al., 2018). It was found that the ability to generate power rapidly as one ages associates the time-dependent changes in one’s function (Drissche et. al., 2018). The dynamometer reliability and validity when being used in an older population holds true, enhancing the importance of its use for rehabilitation, clinical processes, and research for an aging population (Driessche et. al., 2018). An isokinetic dynamometer is a reliable and valid method to assess the parameters of muscle strength and muscle power (Webber & Porter, 2010; Habets et. al., 2018; Drouin et. al., 2004). The association of muscle strength and power to functional performance is of great importance. Through dynamometer assessment, and as demonstrated through various experiments, functional performance can be predicted. The knee extension movement, a single-joint evaluation, is used by the dynamometer to assess function as it targets the lower body muscles of interest directly. This is different than the method the kBox uses, which is multi-joint and will be discussed following, but it is important to note that although the methods are different, both can assess lower limb strength, power and overall, function.

2.7.4 Limitations

Although this is an effective method in evaluating strength, power and functional ability, there are limitations of the dynamometer. First, it has been noted dynamometers are expensive pieces of equipment, limiting its accessibility and usage (Nomura et. al., 2018). The economic cost may deter clinicians from investing in such equipment, resulting in limited care, diagnosis, and treatment options for patients. Second, the isokinetic dynamometer equipment is large in size, rendering it not transportable (Nomura et. al. 2018). This also increases inaccessibility due to possible travel requirements for patients as well as clinicians. Lastly, the knee extensor motion does not encompass all movement associated with activities that are performed on a daily basis limiting the dynamometer's ability in predicting functional ability (Schoenfeld & Contreras, 2012). Multi-joint training is reflective of daily life and produces similar physiological adaptations as single-joint training. Therefore, the knee extensor motion is limited in predicting functional ability whereas the use of a squat for evaluation may be more reflective. These three limitations are key constraints of a dynamometer's capability of accurately predicting function in an aging population. This being noted, these limitations may have been overcome by the development of flywheel systems, such as the kBox which is capable of providing real-time data outputs and assessment of various parameters.

2.7.5 kBox4 Flywheel

The kBox4 is a flywheel device developed by Exxentric, AB, Sweden in 2011. This device has become popular training equipment among the young, strength-trained population as well as competitive athletes (Maroto-Izquierdo et. al., 2017; Hoyo et. al., 2016; Hoyo et. al., 2015). The kBox4 is comprised of a base/platform, a drive belt, a flywheel attachment, various harness sizes, an attachment piece for the drive belt to the harness, various exercise attachments, and the kMeter. Four different inertia wheels are provided by Exxentric, ranging from 0.01, 0.025, 0.05 and 0.07kgm^2 . The various inertia effect velocity, force output, power, volume, total work, degree of eccentric load and ultimately the training adaptation. Typically, smaller inertia plates are used when speed is desired, and commonly are utilized during warm-up sessions. Larger inertia plates usually have a decreased speed and are used when strength, control and a production of eccentric overload is desired (Exxentric, 2019). This device utilizes the flywheel capabilities and inertia to provide high and variable resistance through a full range of motion (Exxentric, 2019). The resistance is variable based upon the user. The user is working against the inertia of the flywheel and the effort one puts into the initial motion of a contraction is the energy stored in the wheel, and released in the second phase of a contraction. The resistance is dependent upon the effort initially put into the wheel, is variable, and unlimited through the contraction range of motion. Due to the unique design of the kBox4 (Figure 6), it is capable of eccentric focused training. The kBox4 can provide increased eccentric workloads through training regimes (Exxentric, 2019). This form of training has multiple benefits for an aging population.

2.7.6 Eccentric Training and Eccentric Overload

The flywheel in the kBox4, is capable of eccentric training as well as eliciting eccentric overload. Eccentric overload is when the eccentric force under tension is greater than the maximum concentric force during a contraction/movement (Exxentric, 2019). Eccentric overload occurs when the force applied during the concentric phase of contraction is the rotational acceleration gained by the flywheel device at the base of the apparatus. The release of the stored rotational kinetic energy occurs during the eccentric phase of contraction and is greater than that applied previously, resulting in eccentric overload (Hoyo et. al., 2015; Tesch et. al., 2017). The eccentric overload protocol, called the kBox SPT, developed by Exxentric may have important implications for exercise prescription in an aging population. Recently, the benefits of eccentric overload training are beginning to be documented across ages and pathologies. Eccentric overload produces great stimulus for muscles which is essential to gain the benefits known from strength training (Norrbrand et. al., 2008). The important implications of working

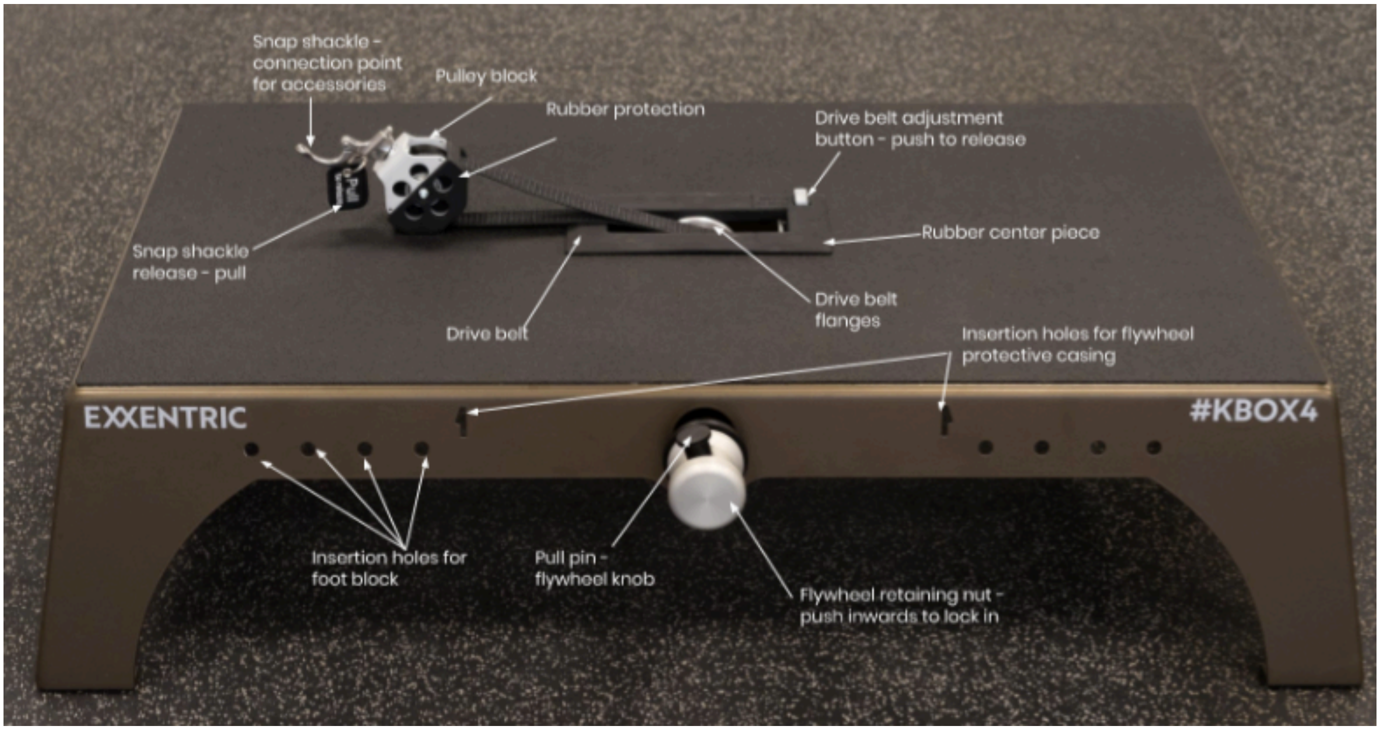


Figure 6: the kBox4 Pro flywheel equipment designed by Exxentric, AB, Sweden. Its mechanical components are labelled (Exxentric, 2019).

eccentric actions leads one to question the true applicability in a senior population. There is no known research examining its applicability in a clinical setting and little literature explores eccentric overload applications in a senior population, especially in regards to its ability to be predictive of functional performance. The kBox allows for evaluation of both muscle force and power and therefore holds the possibility of being an alternate tool in place of a dynamometer.

2.7.7 Measures of Muscle Strength, Power, and Predictability of Functional Performance

The kBox4 is capable of measuring both muscle force/torque (strength) and power. These measurements are important when assessing function in seniors, demonstrating the possible capabilities and clinical application the kBox4 may contain. Bollinger et. al., 2020 assessed outputs of average power, peak concentric and eccentric power, average force, average speed and total work of the kMeter of the kBox4. It was noted that variability exists between individual motions and therefore recommends multiple testing sessions to enhance reliability for those unfamiliar with the kBox methods (Bollinger et. al., 2020). When examining validity, it has been found that some systematic error exists when evaluating mean force and power, but not peak force and power, and these authors suggest that using mean data may not be as appropriate as peak data for research purposes (Weakely et. al., 2019). Further research is required to determine the ability of the kMeter to measure all parameters listed previously. The relationship between power output and torque with the kBox can be compared to that of the "gold standard" dynamometer outputs (Stark et. al., 2011; Drouin et. al., 2004)

2.7.8 kBox 4 Flywheel Overcoming Dynamometer Limitations

The kBox4 overcomes the financial limitation as its price is much less in comparison to a dynamometer (Exxentric, 2019), making this more affordable for clinicians, increasing accessibility, and evaluation opportunities. Secondly, the kBox4 is much smaller than a dynamometer and can easily be transported. The inertia wheel can be removed from the device and stored in a transportable bag supplied by Exxentric. The base is easy to lift and both the harnesses and inertia plate can be transported to desired locations (Exxentric, 2019). Third, the lower limb evaluation conducted on a dynamometer is a knee extension motion whereas the kBox4 lower limb evaluation is performed by squatting. A squat motion encompasses movements that are more reflective of day-to-day tasks such as climbing stairs, gardening or standing from a chair, and therefore could be more predictive of functional performance in an aging population, making it applicable in a clinical setting. Encompassing physiological parameters when comparing isokinetic dynamometer and the kBox4 will provide insight into the similarities or differences in each evaluation modality through muscle activation patterns, amplitudes, and the various metabolic demands of the muscles.

2.8 Conclusion

This literature review began by noting the physiological adaptations of aging. This section demonstrated the common physiological factors affected, which encompass muscle strength and power. The discussion of multiple combative measures highlighted the importance of maintaining muscle strength and power as one ages, with the importance of eccentric training in a senior population emphasized. The importance of muscle strength and power in relation to functional ability and the traditional methods of evaluation were explored, both being commonly assessed by an isokinetic dynamometer. The concept of functional ability is highly dependent on muscle strength and power. It can be evaluated through many well-established functional tests. When assessing lower limb function, it was determined that three key functional tests should be used. These tests include the TUG, FTSTS and SCPT. The method traditionally used to assess muscle strength and power was the evaluation conducted by an isokinetic dynamometer, known as the "the gold standard" of assessment. Although multiple benefits are noted regarding the use of dynamometers, limitations include accessibility barriers stemming from price and transportability in addition to the movement evaluation applicability in daily life. A possible alternative to the dynamometer is the kBox4, a flywheel device capable of eccentric overload, highlighting the benefits of eccentric exercise and the recording of multiple parameters. The necessity to research the validity of the kBox and its potential to predict functional performance was highlighted throughout the literature review, especially with Canada's aging population. Therefore, the three research objectives are as follows:

1. To determine the relationship of the isoinertial kBox flywheel power and torque outputs in comparison to the gold standard dynamometer. This will provide insight if the kBox may be an alternate tool for the dynamometer.
2. To determine if the isoinertial kBox flywheel is predictive of functional performance in comparison to the dynamoemter's ability to predict functional performance.
3. To gain physiological insight into the various modalities through sEMG recordings and muscle oxygenation.

The hypotheses for the research objectives are:

1. The isoinertial kBox flywheel power and torque outputs during squatting will correlate with the power and torque ouptuts of the isokinetic dynamometer, displaying good validity of measures.
2. The isoinertial kBox flywheel will be more predictive of functional performance during squatting than the isokinetic dynamometer during knee extension.
3. The muscle deoxygenation and the muscle activation will be greater during the isoinertial kBox flywheel squatting protocol and functional performance tests than during the knee extensions of the isokinetic dynamometer.

Chapter 3: METHODOLOGY

3.1 Introduction

This section addresses the procedure conducted when examining eccentric squat loading as means of assessing physical function in a senior population and the possible physiological effects it may elicit. The ethical considerations, research design, participants, instruments and measurements, and specific machinery protocols are discussed.

3.2 Ethical Considerations

This research was approved by the University of Saskatchewan Biomedical Research Ethics Board in January 2019. A signed consent form (Appendix A), was required by all participants which outlined the details of the study, procedure, purpose, and possible risks. All participants completed and signed a Get Active Questionnaire (GAQ), (Appendix B), to minimize risk associated with participation in physical activity. Participants were informed their participation was confidential and completely voluntary in which they could withdraw as a participant at any period in the study.

To ensure confidentiality was maintained throughout the research process, no names appeared on any of the data. Instead, participants were assigned a code which was used throughout the data collection and analysis process. Data collected on the EMG equipment was stored in a locked cabinet in a key-coded room. Data collected on the muscle oxygenation equipment, the NIRO-200X, the kBox and the dynamometer was transferred immediately to the primary research computer which was passcode locked. Functional test data, which was recorded on data collection sheets stored in a locked cabinet, was immediately transferred to the primary research computer.

3.3 Research Design

A cross-sectional, within participant design was appropriate due to the comparisons being conducted across exercise modalities and physiological parameters because cross-sectional within participant designs are useful when looking at relationships among variables over a short period of time (Spector P.E. 2019). A quantitative design was appropriate for this study because there was no current information regarding the kBox and its potential to predict functional performance in a senior population. A quantitative output comparison provided insight into the research questions. All participants attended a total of two testing sessions which were separated by at least 48 hours in order to minimize muscle fatigue.

3.4 Sample Size and Participants

Sample size was calculated using an equation established by Hulley et. al., 2013. Alpha, α, the probability of type I error, was set at 0.05 and β, the probability of a type II error, at 0.20. These values fall within the acceptable range and produce a power of 0.80 (Hulley et. al., 2013). The correlation coefficient was estimated at $r = 0.6$, by using Hylley et. al., 2013. This value has been shown in other studies to be approximately the smallest correlation found by previous research examining the relationship between muscle strength and functional performance in older adults (Roig et. al., 2010; Jung & Yamasaki, 2016). The calculation determined 19 participants are required to yield significant results. Due to the inclusion criteria as well as the short duration of the study, large dropout numbers were not expected and therefore the aimed number of participants to recruit was 20 individuals.

Participants recruited for this study were required to be between the ages of 55-85, currently strength training, specifically familiar with squatting, and have no cardiovascular or musculoskeletal complications that would limit their ability or increase risk to participate. Due to the inclusion criteria, individuals were recruited from various strength training facilities located in Saskatoon, SK, including Synergy Strength and Conditioning, Reebok Crossfit 306, and ProActive Fitness. A visual representation of the recruitment process is provided (Figure 7). A total of 26 strength trained individuals were recruited and volunteered to participate in this study, see Table 2 for the breakdown of the demographics for this study.

3.5 Measurements

The following breakdown of instrumentation measurements is to provide insight to the measurements taken, how they were taken and the reason for their collection. The following measurements were all collected to assist in answering the hypotheses presented earlier.

3.5.1 Dynamometer Measures

The dynamometer was used in recording quadricep muscle outputs through the motion of a knee extension and flexion with concentric and eccentric tests conducted at a speed of 60 degrees/second. The raw outputs for the both the concentric and eccentric tests include peak torque (ft/lbs), work per repetition, average power (W), joint angle at peak torque (deg), range of motion (deg), time to peak torque(s), and time peak torque held (Computer Sports Medicine, 2006). The raw outputs for the isometric test include peak torque, joint angle at peak torque and

Table 2: Demographic breakdown of the 26 participants involved

Factors	Male (n=9)	Female (n=17)	All (N=26)
Age (years)			
Mean ± SD	62.8 ± 6.4	62.8 ± 6.3	62.8 ± 6.2
Median	63.0	61.0	62.0
Height (cm)			
Mean ± SD	177.5 ± 6.9	163.2 ± 5.3	168.2 ± 9.1
Median	177.8	163.0	167.6
Weight (kg)			
Mean ± SD	89.9 ± 14.4	69.4 ± 10.7	76.5 ± 15.4
Median	90.9	65.9	70.5
Training Experience (min/week)			
Mean ± SD	193.3 ± 148.7	215.3 ± 173.8	207.7 ± 162.9
Median	180.0	135.0	147.5
Range	500.0	660.0	680.0

time to peak torque. The data collected from the concentric and eccentric protocols are real-time data where speed is controlled and ROM was set. From the raw data collected, the peak torque, average power, peak power and rate of torque development were all used for assessing functional performance during analysis. The best trial of the three conducted was used when assessing power and torque outputs.

3.5.2 kBox Recordings

The isoinertial kBox flywheel device utilized the kMeter app to record multiple outputs during the SPT. The kBox SPT utilized the multi-joint movement of a squat to produce these recorded outputs and although speed cannot be controlled, the data collected was at a similar speed to that of the dynamometer (60 degrees/second). The raw outputs produced by the kMeter include both concentric and eccentric average power (W), peak power (W), velocity (deg/s), range of motion (deg), degrees, average force and peak force (N), percent overload (%), and energy (kJ). It also produced real-time data for each repetition of each trial that included speed rotations and time (Exxentric, AB, Sweden, 2019). For our purposes, the best trial (maximum outputs produced) was used for analysis. In Bollinger et. al., 2018, it was confirmed that the kBox displayed acceptable validity, but the reliability varied between lifts and specific outcomes. The recommendation put forth was to conduct multiple testing sessions to enhance reliability for those unfamiliar with the kBox methods (Bollinger et. al., 2018). The recommendation by Bollinger et. al., 2018 was accounted for in the protocols that follow. From the raw data collected, concentric and eccentric peak power, peak torque, and average torque were used in analysis when evaluating predictability of functional performance.

3.5.3 Functional Test Measures (FTSTS, TUG and SCPT)

For each functional test, the time in which the participants completed the task, in seconds, was recorded. A practice trial and two test trials of the FTSTS, TUG and SCPT were performed (Bohannon, R. W., 2006). The fastest trials for each test were used for power and strength analysis as well as EMG and MO analysis.

3.5.4 Muscle Oxygenation

Muscle oxygenation parameters were measured using a near infrared spectroscopy device, the NIRO-200X, manufactured by Hamamatsu, Japan. The NIRS equipment contains a light source to generate NIR light, a probe to direct the light into the tissue of interest and a detector which determines the muscle oxygenation through the detection of oxyliable chomophors of the desired tissue (Kennedy et. al., 2006; Scheeren et. al., 2012). Tissue oxygenation index (TOI), which represent the dynamic balance of oxygen supply by the muscle microcirculation and the oxygen demand by the muscle, was utilized in comparing the various muscular and vascular changes between each exercise modality (Muthalib et al., 2010).

The one factor that is alterable through testing is the placement of the electrode. When assessing lower limb oxygenation, previous literature indicates the VL is the muscle of interest (Mancini et. al., 1994; Mancini et. al., 1994). Through examining previous studies using a knee extensor motion, the most common placement of the NIRS electrode has been on the distal portion of the VL (Mancini et. al., 1994; Kennedy et. al., 2006). Kennedy et. al., 2006 examined the MO readings based upon different locations of electrode placement on the VL. It was found that MO was significantly different between distal and proximal locations (Kennedy et. al., 2006). This demonstrates the importance of standardizing placement of the electrode based on desired muscle, and type of exercise/evaluation being conducted.

3.5.5 EMGworks and Acquisition (%MVC)

Muscle activation was recorded using sEMG electrodes from a Delsys Tringo Wireless System. Data was stored and analyzed by the EMGWorks Acquisition program (De Luca, G. 2003). The signal bandwithwas 20-450 Hz and the sampling rate was 2000samples/sec. The Delsys program includes high performance analog filters for signal analysis and instrumentation noise management (De Luca, G. 2003). These filters are built-in to ensure the full bandwidth of the EMG signal. For this study, the peak amplitude was of interest to determine which modality evoked the greatest muscle activation. All data for each muscle went through the remove mean function to ensure data was not skewed. From there, amplitude analysis occurred where the software performs RMS (root mean square) on the input data and normalizes it against the MVC trial for that specific muscle.

3.6 Procedure and Protocols First Testing Session

The first testing session occurred at the University of Saskatchewan Science of Rehabilitation lab after an initial screening process was conducted to determine if the individual met the outlined inclusion criteria to be a candidate. When deemed as a possible participant, individuals were sent the consent form through email, or delivered in person. Individuals were required to bring gym appropriate clothing and the consent form to the first testing session. The first testing session included completion of a standardized warm up, the placement of both NIRO-200X and Delsys electrodes, maximum voluntary contraction (MVC) recordings, and completion of the three functional tests: the TUG; the FTSTS; and the SCPT. All functional tests were led by the primary researchers and conducted in random order for every participant to avoid results skewed by possible muscle fatigue. The procedures followed for the tests conducted on day one are described below.

3.6.1 Standardized Warm-Up

For both testing sessions conducted, participants completed a consistent standardized warm-up. This warm-up included participants usual mobility routine which they would typically conduct before a training session. Since individuals participating in this study were familiar with strength training and performed strength training on a weekly basis, participants completed the warm-up procedure they typically conducted before a strength training session. The warm-up activities conducted prior to the first testing session were noted by each participant, and the same procedure was followed subsequently for testing session two. Various warm-up activities included lunges, incremental squat work up, cycling and cardio-work. Once participants indicated their warm-up was complete, they were directed to take a seat in a chair to place both muscle oxygenation electrodes as well as electromyography electrodes on their right quadricep.

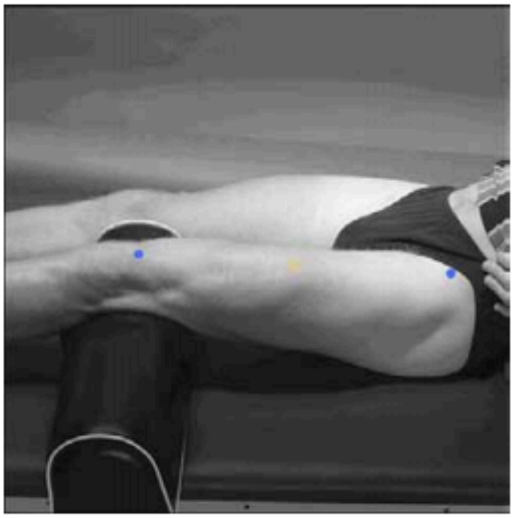
3.6.2 Muscle Oxygenation Electrode Placement

Muscle oxygenation was measured using a near infrared spectroscopy (NIRS) device (Figure 4). The electrodes of the device were attached to the midpoint of the vastus lateralis muscle of each participant (Appendix C). Once the electrodes were placed on the mid-point of the vastus lateralis, they were traced using permanent marker to ensure consistent and standardized placement for the following testing session. The electrodes were attached to the skin by the use of medical tape and then covered by tensor bandages. Tensor bandages were used to eliminate outside light from entering the electrodes preventing the potential of skewing readings. A limitation of using the NIRO-200X was the restricted mobility of the participants due to the recording wires. Therefore, functional tests could not be recorded using this equipment, hindering the scope of investigation of these movements.

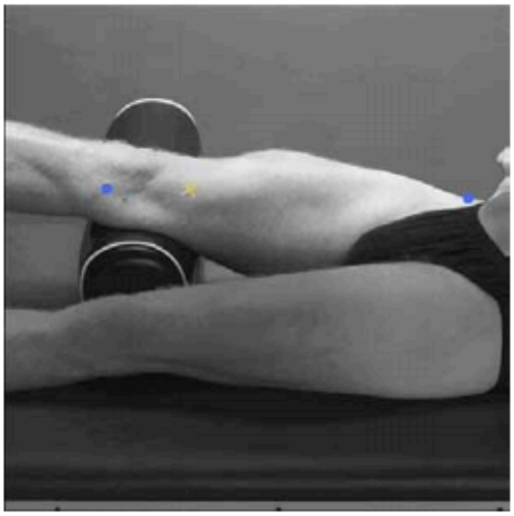
3.6.3 EMG Electrode Placement

For both testing sessions, EMGworks software and electrodes were set up approximately 45 minutes before participant arrival to ensure systems were correctly working and electrodes were charged. Software and electrode set up for each testing day was tested prior to recruiting participants (Appendix C). The electrodes indicated in the protocol to be used were removed from the base station and wirelessly connected. Once connected, adhesives were placed upon the electrodes. Measurements were made according to the SENIAM guidelines (Figure 7) to ensure electrode placement was correct and consistent for each muscle examined. The muscles examined included the vastus lateralis (VL), the vastus medialis (VM) and the rectus femoris (RF). The bulk of the muscle was confirmed by having participants flex their quadriceps for visualization. Once measurements were complete and muscle bulk was confirmed, the electrode placement was marked on the participants VL, VM, and RF. Both the electrodes and participants' skin were cleaned with isopropanol and let dry. If excess hair existed upon place of attachment, it was shaved and then cleaned with the isopropanol (De Luca, J.C. 2002, SENIAM, 1999). Once the skin and electrodes were properly prepared, the one side of the adhesive was removed to reveal the adhesive layer beneath and attached to the marked spots. The placement was checked by having participants flex their leg so the researcher could identify if the

Anatomy	
Subdivision	
Function	Extension of the knee joint and flexion of the hip joint
Placement	
Start Position	Sitting on table, knees in slight flexion upper body slightly bend backward
Location	At 50% of line *anterior spina iliac superior -anterior border of the medical ligament*
Orientation	Almost perpendicular to line *anterior spina iliac superior -anterior border of the medical ligament*
Test	Extend knee while pressing against the leg above the ankle in the direction of flexion



Anatomy	
Subdivision	
Function	Extension of the knee joint and flexion of the hip joint
Placement	
Start Position	Sitting on table, knees in slight flexion upper body slightly bend backward
Location	At 50% of line *anterior spina iliac superior -superior part of patella*
Orientation	Almost perpendicular to line *anterior spina iliac superior - superior part of patella*
Test	Extend knee while pressing against the leg above the ankle in the direction of flexion



Anatomy	
Subdivision	
Function	Extension of the knee joint and flexion of the hip joint
Placement	
Start Position	Sitting on table, knees in slight flexion upper body slightly bend backward
Location	At 2/3 of line *anterior spina iliac superior -lateral side of patella*
Orientation	In the direction of muscle fiber
Test	Extend knee while pressing against the leg above the ankle in the direction of flexion

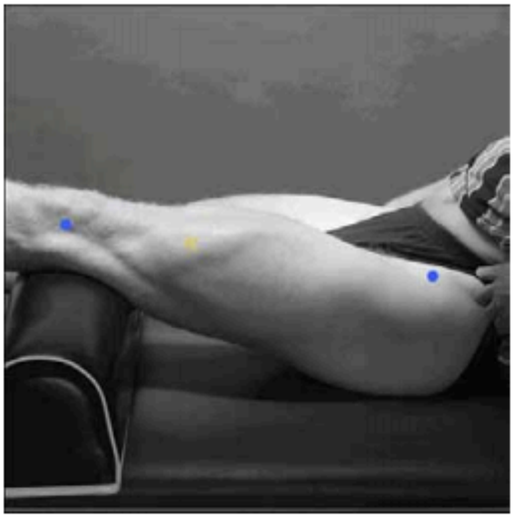


Figure 7: SENIAM guidelines for sEMG electrode placement on the VL, VM and RF.

electrodes were placed on the bulk of the muscle. The placements of the electrodes were further secured by wrapping a tensor bandage around the leg and to minimize outside noise.

3.6.4 Quiet Standing Trial

Once muscle oxygenation electrodes and electromyography electrodes were correctly and securely placed upon participants' right quadricep, a quiet standing trial (QST) was conducted. The purpose of the QST was to ensure all equipment was correctly working and that baseline recordings of muscle activity were recorded for normalization during analysis. For this trial, participants were asked to stand in a relaxed stance and remain quiet for the duration. Once indicated, the recording of baseline muscle activity commenced. Baseline recordings lasted for a total of two minutes. Upon completion, participants were directed to the dynamometer to record maximum voluntary contractions (MVC's).

3.6.5 MVC Recordings

Through the use of a dynamometer, MVC recordings were conducted by having participants hold a sustained isometric maximal effort contraction of the knee extensors at flexion 60-degree angle for 5 seconds for a total of three trials (Halaki & Ginn, 2012). The purpose for conducting MVC's was two-fold; first, MVC measurements were required to later normalize the collected data (De Luca, J.C. 2002, Halaki & Ginn, 2012, Day, S. 2018) and second, to familiarize participants with the dynamometer before testing day two. For the VL, VM, and RF, MVC was achieved on an isokinetic dynamometer through an isometric contraction at a 60-degree angle (Hsu et. al., 2006)

For each participant, the HUMAN NORM dynamometer was adjusted to each individuals' measurements to ensure proper alignment for the testing sessions (Appendix C). For the isometric protocol conducted on the dynamometer, participants were provided three practice repetitions with an incremental build-up to maximum contractile effort, followed by a 30-second break. Participants were cued to extend their knee through the countdown initiated by the primary researcher. The countdown and encouragement provided to participants during the practice session was identical during the test trials. After practice repetitions were complete, participants executed three maximal contractions, each separated by a 30-second break to minimize muscle fatigue (Halaki & Ginn, 2012). The MVC measurements were recorded using the Delsys wireless system. Power, torque, and time to peak torque were recorded by the dynamometer.

3.6.6 TUG

The equipment needed for this test included a tape measure, chair, stopwatch and any additional assistance devices individuals required (Jacobs & Fox, 2008). Equipment was set up before participant arrival, with both the starting mark and three-meter mark indicated by tape markers on the ground. A pilon was set at the three-meter mark allowing easy visualization of the point to change direction. A standardized chair was used for every individual with the height being recorded at 44.70 centimeters. The protocol for the TUG was demonstrated by the primary researcher, followed by a practice trial from the participant. Subsequent the practice trial, two test trials were conducted, with the best results used for analysis (Bohannon, RW., 2006).

3.6.7 FTSTS

Equipment was set up before participants arrival including the standardized chair as indicated previously, with a height of 44.70 centimeters. The protocol for the FTSTS was demonstrated by the primary researcher, followed by a practice trial for the participant. In this task, individuals began seated in the chair with their arms folded across their chest. When instructed, participants stood and sat back down as fast as they could using a controlled motion for a total of five repetitions (Bohannon et. al., 2010; Wallman et. al., 2013; Blackwood, J., 2017). The FTSTS was conducted for a total of two trials, with the best score used for analysis.

3.6.8 SCPT

For this task, participants are timed for the duration required to ascend 10 stairs, instructed to not use the hand-rail, and to take one stair at a time with a stair height approximately between 16-20 centimeters (Westby et. al., 2015). The equipment required for this task included a stop-watch and a set of stairs. The stairs used to conduct this test had a stair height of 17.10 centimeters. Participants were escorted to the stairwell closest to the testing room in the School of Rehabilitation Science. Participants were positioned on the 10th stair down to ensure the stop of the test was easily marked as the top of the stair case. The primary researcher demonstrated the protocol, using an identical countdown script when timing participants. Participants were subsequently allowed a practice trial, followed by two test trials. Each step was ascended one step at a time, with one foot being placed on the step (not both feet). The best time between the two test trials was recorded and used in analysis.

3.6.9 kBox Practice Session

Following the completion of all functional tests, participants were provided a practice session on the kBox equipment to ensure familiarization, comfortability and confidence in participants. The kBox mechanics were not known to all participants and therefore familiarization was important in order to prevent skewed results on the second day of testing (Bollinger et. al., 2018). Following removal of electrodes, participants stood and were fitted with a kBox harness. When the harness was snug above the waist and the shoulder pads were resting comfortably, the harness was determined to be fitted. The harness size was recorded by the primary researcher to ensure efficiency and consistency for the second testing session. The primary researcher demonstrated the mechanism of the kBox and the SPT for each participant before individuals were permitted to step on the kBox. Participants aligned their stance to the center of the kBox axis indicated by the primary researcher. Individuals were then attached to the kBox device through the attachment of the harness to the inertia wheel cable. Proper tension was placed on the cable by pulling the cable tight when participants had their knees slightly bent. Participants were instructed to start with normal squatting at a slow pace in order to familiarize themselves with the kBox equipment before moving into the SPT practice. Participants performed standard squats on the kBox until they felt comfortable with extending, flexing and the rhythm of the kBox device. When indicated, the primary researcher slowed the inertia wheel to a stop and allowed participants a brief break before moving into the SPT practice.

The SPT practice required individuals to conduct a total of 7 squats on the kBox, with the first two squats building momentum in a single 0.05 kg/m^2 inertia wheel and the five remaining squats to be conducted at 80% effort following the overload protocol (Exxentric, AB, Sweden, 2019). A minimum three-minute rest was provided followed by a second practice of the SPT protocol. With the eccentric practice, individuals moved upwards from their squatting stance (concentric phase) at a faster rate than during the two build-up repetitions. When the top of the squat was reached, participants immediately sat into a quarter squat and waited for the load to pull them down eccentrically, resisting the pull. When the fifth repetition was complete, the primary researcher slowed the inertia wheel to a stop. The quarter squat stance depth was normalized for each participant using Bower Timing Systems, Draper, UT timing gates to indicate they had achieved the appropriate stance before the eccentric pull. The height for the timing gates varied between participants due to individual differences, but a goniometer was used to ensure the timing gates were set up where the squat angle indicated a quarter squat, which was approximately 135-degree flexion of the knees and the timing gates were set up where the individual's glutes crossed at this position. Timing gate heights were measured and recorded to be used during set up for the second testing session to ensure efficiency and consistency. A visualization of the timing gate set-up protocol and participant timing gates can be found in Appendix C. Participants were verbally encouraged by the primary researcher during the eccentric load practice identical to the encouragement they would receive in the second testing day.

3.7 Protocol's Second Testing Session

The second testing session occurred following a minimum break of 48 hours from the first testing session to minimize muscle fatigue. This session included the completion of the standardized warm up, the placement of electrodes, kBox SPT, the dynamometer concentric test, dynamometer eccentric test and the dynamometer isometric test. The protocol for the second testing session was randomized for all participants to ensure results were not skewed in the case of possible muscle fatigue. Protocols for the standardized warm-up and placement of both muscle oxygenation and EMG electrodes as previously discussed above and were identical for the second testing session with electrodes being placed at the traced marks. Therefore, they will not be discussed as part of the protocols for the second testing day.

3.7.1 kBox Squat Power Test (SPT)

They main goal of this study was to assess the ability of the kBox to predict physical function in seniors in comparison to the HUMAC NORM Dynamometer. The SPT was conducted for a total of three test trials, each separated by a required three-minute break (Exxentric, AB, Sweden, 2019). For each trial, participants were required to conduct a total of 7 squats; the first two building momentum in the $0.05 kg/m^2$ inertia wheel and the following 5 being completed at 100% maximal effort.

The equipment including the kBox, harnesses, $0.05 kg/m^2$ inertia plate, kMeter, and timing gates were set up prior to participant arrival. The timing gate height was set to the height previously recorded during the practice session on the first testing day. After completion of the standardized warm-up and electrode placement, participants were fitted with the harness they had previously used during the practice session. The primary researcher demonstrated the SPT to participants to ensure the protocol was understood. Again, similar to the practice session, participants stood on the kBox base and aligned their center of gravity with the assistance of the primary researcher. The harness was then attached to the inertia cable by placing the red inseams together. Participants slightly bent their knees and tension was increased on the cable by the researcher. Tension in the cable was confirmed by participants and adjustments were made if necessary. Participants were lowered into their squatting stance (approximately 90-degree flexion of the knees) and the researcher tightened the cable by spinning the inertia plate. The researcher started the kMeter recorder as they counted down from three, initiating the start of the SPT protocol. Participants moved upward from the squatting stance concentrically and back down eccentrically, indicating the completion of the first warm-up repetition. When the two warm-up repetitions were complete, the primary researcher verbally reminded participants to move to the quarter squat stance immediately once the top of the squat was reached and to resist the eccentric pull. Participants moved concentrically with 100% effort and once the top of the squat was reached, immediately sat into their quarter squat stance, indicated by the buzz from the timing gates. The load of the inertia plate pulled them down eccentrically, with participants resisting the pull with maximum effort. This movement was conducted for the following five repetitions. Immediately after the completion of the fifth repetition, the researcher slowed the inertia plate to a stop. The participant was detached from the inertia cable allowing them to stretch their legs between trials during the three-minute break. The participants completed two more trials of the SPT protocol, each separated by a minimum three-minute break. While participants were stretching or grabbing water between trials, the researcher saved the average and real-time data to the kMeter app and emailed the data to a trusted email account. This data was later transferred to an excel file for analysis. With all three trials complete, the participant stepped down from the kBox and removed the harness.

3.7.2 Dynamometer Concentric, Isometric, and Eccentric Test Protocols

Before participant arrival, the dynamometer chair settings were adjusted to the values previously recorded during the practice session in the first testing session. The details regarding this protocol set up and the range of motion (ROM) settings can be viewed in Appendix C. Once electrodes were attached, participants were directed to take a seat in the dynamometer chair. Participants were strapped in by the shoulder harness as well as the quadricep strap. The use of the dynamometer was reviewed with participants including what tests would be conducted that day and what measurements were being recorded. Participants were shown the side handles and were instructed to use these for leverage throughout the tests. The isometric test that occurred on this test day was identical to the isometric test conducted and described on the first test day. Section 3.6.5 references detailed information regarding the isometric protocol are applicable to this discussion.

The concentric test began with participants resting in full flexion. On cue through a countdown initiated by the primary researcher, participants were to extend fully, as hard and as fast as they could. Once complete extension was reached, which was marked by the ROM set previously, participants were to relax their leg back to flexion. Participants were provided three practice trials, consisting of an incremental work up to maximum effort. Once the practice trials were concluded, participants were required to complete five maximum effort extensions on the dynamometer, with a 30 second break in between. Participants were provided the identical countdown and verbal encouragement by the researcher through all repetitions.

The eccentric protocol started with the primary researcher raising the participants' leg to a fully extended position. This was the starting stance, with the participant's leg being locked in place by the dynamometer. Upon cue, with the same countdown conducted in other tests, the participant was instructed to push upwards against the pad located directly above the lateral malleolus. When pressure was placed upward on the pad, the dynamometer began the eccentric protocol. The arm of the dynamometer pushed downwards on participants' legs, moving them from full extension to full flexion. During this movement, participants resisted the downwards push with maximum effort. Participants were provided three practice trials consisting of an incremental workup to maximal effort. Five test trials were conducted at maximal effort with identical countdowns and verbal encouragement from the researcher. Participants were provided a 30 second break between each maximal repetition, to ensure the starting position was properly attained by the researcher.

Data collected for each test on the dynamometer was saved by time stamp and date. Data was immediately transferred to the researcher's computer and organized into Microsoft Excel files for analysis. Participants were released from the dynamometer by removing the shoulder harness and quadricep strap. Participants were allowed to walk around and stretch.

3.8 Description of Data Analysis

Based upon tests of central tendency and variance, the data collected was described using parametric methods. All quantitative data was analyzed using the Minitab 19.2020.1descriptive statistical analysis package (Minitab LLC; Chicago, IL). For all analysis, confidence intervals and effect size were calculated. Alpha, α, was set at a priori of 0.05. Specific data analysis procedures for each hypothesis are discussed below.

3.8.1 Hypothesis of kBox and Dynamometer Correlations

Pearson's product moment coefficient calculation was conducted for all power and torque outputs produced from the kBox and Dynamometer to determine correlations. Correlations between 0.3 to 0.5 were considered low, 0.5 to 0.7 were considered moderately correlated, 0.7 to 0.9 were considered highly correlated, and from 0.9 to 1.0 were considered very highly correlated (Mukaka, M., 2012).

3.8.2 Hypothesis of Predictability of Functional Performance

Pearson's product moment coefficient calculation was performed using Minitab for each functional test to determine if the kBox flywheel outputs and the Isokinetic Dynamometer outputs were correlated, which displayed the predictability potential. The same correlation conclusions were used as listed above (Mukaka, M., 2012). To further investigate which, if any, kBox or dynamometer measures were of greater significance in predicting functional performance, a linear multiple regression analysis was conducted for each functional test. Multiple linear regression enabled investigation into the roles the numerous variables recorded by both the kBox and Dynamometer played in predicting functional performance (Nathans et. al., 2012).

3.8.3 Hypothesis of Muscle Oxygenation and Muscle Activation between Modalities

EMG analysis commenced with the determination of the reliability of measurements between testing day one and testing day two. MVC torque values recorded by the isokinetic dynamometer on each test day were utilized when determining measure reliability. Pearson's product moment coefficient calculation was performed. This included the production of means, standard deviations and Cronbach's Alpha. Additionally, intraclass correlation was produced to ensure reliability of measures (Koo & Li, 2016). This step was also done for the raw data of the vastus lateralis, vastus medialis, and the rectus femoris. Once reliability of measures was determined, %MVC recorded by EMGWorks could be further investigated. One-way ANOVA analysis was conducted for each muscle. Each ANOVA included six factors; the TUG data, FTSTS data, SCPT data, dynamometer concentric data, dynamometer eccentric data, and the kBox data. The one-way ANOVA displayed whether there was a difference of means between groups (Kim, T., 2017). If the ANOVA displayed a significance between group means, Tukey Pairwise Comparison and a Tukey Simultaneous Test for Differences of Means was conducted to investigate which means differ significantly from the rest.

MO analysis included running one-way ANOVA analysis for the various modalities tested. The ANOVA included four factors: the dynamometer concentric test data, the dynamometer eccentric test data, the dynamometer isometric test data, and the kBox flywheel data. As stated previously, no data was recorded for muscle oxygenation during the functional tests due to the non-wireless limitation of the NIRO-200X. For the one-way ANOVA, only repetition one values were used due to the resting states being different between the modalities. If the ANOVA displayed a significance between group means, Tukey Pairwise Comparison and a Tukey Simultaneous Test for Differences of Means was conducted to investigate which means differ significantly from the rest.

Chapter 4: RESULTS

4.1 Introduction and Hypotheses Review

This chapter discusses the analytical procedure, statistical methods, and results of this study. It addresses the results of the following hypotheses:

1. The isoinertial kBox flywheel power and torque outputs during squatting will correlate with the power and torque ouptuts of the isokinetic dynamometer, displaying good validity of measures.
2. The isoinertial kBox flywheel will be more predictive of functional performance during squatting than the isokinetic dynamometer during knee extension.
3. The muscle deoxygenation and the muscle activation will be greater during the isoinertial kBox flywheel squatting protocol and functional performance tests than during the knee extensions of the isokinetic dynamometer.

4.2 Statistical Analysis Results for kBox and Dynamometer Measured Outputs

4.2.1 Pearson's Correlation and ICC for kBox Measured Outputs and Dynamometer Measured Outputs

A majority of the data indicated strong positive correlations between kBox and dynamometer outputs. When comparing direct measures, eccentric peak power of the kBox and dynamometer had the strongest positive correlation of $r= 0.972$, $p < 0.001$. This is considered a very high positive correlation. Concentric peak power between the kBox and dynamometer also displayed high correlation of $r= 0.818$, $p < 0.001$. The correlations for peak torque values between modalities displayed a lesser relationship with only moderate to high correlations. Concentric peak torque of the kBox and dynamometer had a moderate positive correlation of $r = 0.696$, $p < 0.001$. Eccentric peak torque of the kBox and dynamometer had a high positive correlation of $r = 0.782$, $p < 0.001$. Pearson's correlations performed showed eccentric kBox and dynamometers measures to be highly correlated and concentric to be less correlated. Other high positive correlations noted include an $r = 0.866$, $p <0.001$ for concentric peak power of the kBox and isometric peak torque of the dynamometer and an $r = 0.817$, $p < 0.001$ for eccentric peak power of the kBox and isometric peak torque of the dynamometer. An ICC (1,1) = 0.742 was calculated indicating consistency of measurements between modalities.

Table 3: Raw data ouptuts from theisoinertial kBox and isokinetic Dynamometer per participant

	Dyna CON Peak Torque (Nm)	kBox CON Peak Torque (Nm)	Dyna ECC Peak Torque (Nm)	kBox ECC Peak Torque (Nm)
	90.6	436.7	166.8	642.6
	187.7	508.0	297.9	859.9
	145.6	468.1	237.7	707.2
	126.8	413.4	174.1	719.2
	130.6	353.6	169.9	640.2
	118.2	205.8	126.2	397.2
	69.9	348.6	110.1	601.2
	79.5	183.5	123.3	311.6
	167.6	532.4	210.6	982.7
	108.2	240.3	123.3	370.2
	89.4	218.4	123.4	465.3
	104.8	433.3	163.0	731.2
	120.6	459.2	185.9	887.9
	139.0	391.3	220.6	689.8
	129.2	412.5	173.7	626.1
	135.2	467.7	239.9	895.9
	154.5	731.2	283.3	1585.2
	149.3	568.7	224.7	935.6
	121.6	519.6	169.4	992.8
	195.9	812.5	257.5	1476.4
	122.0	361.8	173.0	636.3
	161.1	674.8	244.4	1332.2
	223.5	727.6	279.4	1357.6
	198.4	424.4	222.5	843.3
	90.9	393.1	112.1	678.7
	137.63	339.9	186.9	592.3
Mean	134.5	452.1	192.3	806.1
SD	38.3	156.2	55.5	329.4

Table 4: Isoinertial kBox Flywheel Outputs Pearson's Product Correlations with Isokinetic Dynamometer Outputs

			Isokinetic Dynamometer						
			Peak Power		Peak Torque			Rate of TD	
			Concentric	Eccentric	Concentric	Eccentric	Isometric	Concentric	Eccentric
Inertial kBox Flywheel	Peak Power	Concentric	0.818*	0.769*	0.818*	0.769*	0.866*	0.353	0.580*
		Eccentric	0.808*	0.972*	0.690*	0.782*	0.817*	0.224	0.545*
	Peak Torque	Concentric	0.709*	0.790*	0.696*	0.790*	0.777*	0.177	0.629*
		Eccentric	0.743*	0.782*	0.698*	0.782*	0.785*	0.162	0.589*
	Average Torque	Concentric	0.778*	0.812*	0.751*	0.812*	0.823*	0.189	0.640*
		Eccentric	0.736*	0.748*	0.714*	0.748*	0.791*	0.197	0.552*

*significance value < 0.05

4.3 Statistical Analysis Results for Predictability of Functional Performance

4.3.1 Pearson’s Correlation Between Functional Testss, kBox Outputs and Dynamometer

Table 5: Raw functional test results (s)

	TUG (s)	FTSTS (s)	SCPT (W)
	5.73	5.30	332.85
	4.98	8.68	491.66
	4.05	6.95	417.47
	4.61	5.35	407.22
	4.63	4.63	358.71
	4.55	7.53	473.87
	6.21	9.03	418.24
	5.98	7.55	420.40
	5.10	6.73	474.11
	4.91	7.75	350.25
	5.93	10.15	296.07
	4.18	4.25	359.37
	4.95	4.88	304.74
	4.41	5.56	357.79
	4.51	5.30	399.13
	3.56	4.68	417.96
	4.45	5.51	683.10
	4.51	4.56	521.43
	4.18	5.41	403.16
	4.16	5.91	706.13
	5.51	6.45	439.71
	5.00	5.30	649.53
	3.98	4.89	627.69
	5.29	6.35	703.45
	5.75	6.60	369.37
	4.53	4.96	424.05
Mean	4.83	6.16	454.13
Standard Deviation	0.69	1.52	122.39

Dynamometer Outputs

Pearson's product moment coefficient correlation was conducted for the TUG, FTSTS and SCPT data, for both kBox flywheel outputs and isokinetic dynamometer outputs. The correlations below indicate the strength of relationship between measurements and the potential predictability the kBox and dynamometer may have on functional performance.

Table 6: Isoinertial kBox Flywheel outputs and Functional Tests (FTSTS, SCPT and TUG)

	PP CON	PP ECC	PT CON	PT ECC	AT CON	AT ECC
FTSTS/kg	-0.602***	-0.558***	-0.650***	-0.679***	-0.657***	-0.585***
SCPT/kg	0.602***	0.671***	0.518***	0.583***	0.572***	0.571***
TUG/kg	-0.624***	-0.630***	-0.650***	-0.692***	-0.678***	-0.686***

***significance level <0.05

PP CON = peak power concentric
PP ECC = peak power eccentric
PT CON = peak torque concentric
PT ECC = peak torque eccentric
AT CON = average torque concentric
AT ECC = average torque eccentric
FTSTS/kg = five time sit-to-stand
SCPT/kg = stair climb power (W/kg)
TUG/kg = time-up-and-go

For the isoinertial kBox flywheel device, peak power, peak torque and average power values were analyzed to examine the strength of relationship to functional test results. All correlations produced were significant, with an Alpha, α, set at 0.05. All kBox correlations with the FTSTS test were moderately negative in strength. The greatest correlation was a r(24) = -0.679, $p < 0.01$ for eccentric peak torque. All kBox correlations for the TUG test were also moderately negative in strength. The strongest correlation for the TUG was a r(24) = -0.692, $p < 0.01$ for eccentric peak torque. All kBox correlations with the SCPT were moderately positive in strength. The strongest correlation for the SCPT was a r(24) = 0.671, $p < 0.01$ for eccentric peak power. Eccentric kBox measures seem to display the strongest correlation for all functional tests.

Table 7: Isokinetic Dynamometer Output correlations with Functional Tests

	PP CON	PP ECC	PT CON	PT ECC	PT ISO	RTD CON	RTD ECC
FTSTS/kg	-0.577^{***}	-0.611^{***}	-0.584^{***}	-0.611^{***}	-0.580^{***}	-0.206	-0.554^{***}
SCPT/kg	0.594^{***}	0.530^{***}	0.588^{***}	0.530^{***}	0.576^{***}	0.423^{***}	0.411^{***}
TUG/kg	-0.792^{***}	-0.754^{***}	-0.789^{***}	-0.754^{***}	-0.715^{***}	-0.088	-0.719^{***}

***significance level <0.05

PP CON = peak power concentric
PP ECC = peak power eccentric
PT CON = peak torque concentric
PT ECC = peak torque eccentric
PT ISO = peak torque isometric

RTD CON = rate of torque development concentric
RTD ECC = rate of torque development eccentric
FTSTS/kg = five time sit-to-stand (s/kg)
SCPT/kg = stair climb power (W/kg)
TUG/kg = time up and go (s/kg)

For the isokinetic dynamometer, the outputs used in the correlation matrix include peak powers, peak torques, as well as the rate of torque development. All measurements for the dynamometer except RTD CON were moderately negatively correlated with the FTSTS results. The strongest correlation for the FTSTS was a r(24) = -0.611, $p < 0.001$ for both eccentric peak power and eccentric peak torque. For the TUG results, all correlations were moderately negative in strength except for RTD CON. The strongest correlation for the TUG was a r(24) = -0.792, $p < 0.01$ for dynamometer concentric peak power. The SCPT test had low to moderate positive correlations with the dynamometer measures. The greatest correlation for the SCPT was a r(24) = 0.594, $p < 0.003$ for dynamometer concentric peak power.

When comparing Table 6 and Table 7, all correlations produced for the TUG and FTSTS tests were negative whereas all correlations for the SCPT were positive. The TUG was more strongly correlated to dynamometer measurements. The FTSTS and SCPT correlations were similar between the kBox and dynamometer with neither having a noticeable greater correlation than the other.

4.3.2 Predictors of Functional Test Performance

To further investigate which kBox or dynamometer value is significant in predicting functional performance, multivariable stepswise forward linear regression was performed. For each regression analysis run, the regression equation was produced and the Beta (β) values as well as the p-values were reported.

Table 8: Forward Stepwise Multiple Linear Regression Results TUG, FTSTS, and SCPT

	TUG			
	β	SE	T-Value	P-Value
Weight (kg)	0.02571	0.00693	3.71	0.001*
Age (yrs)	0.034	0.0151	2.26	0.035*
PT CON D	-0.01308	0.00258	-5.06	0.000*

	FTSTS			
	β	SE	T-Value	P-Value
Weight (kg)	0.0467	0.0182	2.57	0.017*
PT CON K	-0.00363	0.00112	-3.23	0.004*

	SCPT			
	β	SE	T-Value	P-Value
Weight (kg)	4.294	0.732	5.86	0.000*
PT CON D	1.352	0.278	4.86	0.000*

*significance level < 0.05

β, parameter estimate; SE, standard error

PT CON D = Dynamometer concentric peak torque

PT CON K = kBox concentric peak torque

The TUG multiple linear regression displayed that weight is significant with $\beta = 0.02571$, $p < 0.002$, age is significant with $\beta = 0.0342$, $p < 0.04$, and concentric peak torque of the dynamometer is significant with $\beta = -001308$, $p < 0.001$. Of all the kBox and dynamometer measurements produced, dynamometer concentric peak torque was the only significant relationship from the regression analysis. The FTSTS multiple linear regression displayed that weight is a significant factos with $\beta = 0.0467$, $p < 0.02$, and kBox concentric peak torque is a significant factor with $\beta = -0.00363$, $p < 0.005$. Of all kBox and dynamometer measurements recorded, kBox concentric peak torque was the only significant factor from the regression analysis. The SCPT multiple linear regression displayed that weight is a significant factor with $\beta = 4.294$, $p < 0.001$, and dynamometer concentric peak torque is significant with $\beta = 1.352$, $p < 0.001$. Of all the kBox and dynamometer measurements produced, dynamometer concentric peak torque was the only significant relationship from the regression analysis for the SCPT.

4.4 Statistical Analysis Results for MO and Muscle Activation between Modalities

4.4.1 Measurement Reliability for EMG Torque Data

To ensure EMG data collected was reliable for analysis, torque data taken from the dynamometer during MVC isometric contractions from testing day one and testing day two were compared. To assess torque reliability, a covariance matrix was run. This produced a Pearson correlation, Cronbach's Alpha and ICC. Pearson's correlation $r = 0.750$, indicated a strong positive correlation between MVC torques recorded for each day. Cronbach's Alpha displayed an acceptable internal reliability was reached with $\alpha = 0.8485$ and ICC (1,1) = 0.7417. Therefore, torque MVC recordings for testing day one and testing day two displayed good reliability (Koo & Li, 2016).

4.4.2 Measurement Reliability for EMG Absolute Voltage for VL, VM and RF

Since the isometric torque data collected was reliable, further reliability checks of the EMGworks data using the absolute voltage recorded for the VL, VM and RF were conducted. Absolute voltage recorded during MVC contractions for testing day one and testing day two were compared using a covariance matrix produced. For each muscle, Pearson's correlation was produced, and Cronbach's Alpha was examined to determine the internal reliability of measurements.

For the vastus lateralis, Pearson's correlation was $r = 0.620$, indicating a moderately positive correlation between testing day one and testing day two measurements. Cronbach's

Alpha displayed an acceptable internal reliability was reached with $\alpha = 0.6991$. For the vastus medialis absolute isometric voltage data, Pearson's correlation was $r = 0.969$, indicating a very high positive correlation between testing day one and testing day two measurements. Cronbach's Alpha displayed an acceptable reliability was reached between measures with $\alpha = 0.9619$. The rectus femoris absolute voltage data displayed a Pearson's correlation of $r = 0.912$, indicating a very high positive correlation between day one and day two isometric recordings. Cronbach's Alpha showed that an acceptable internal reliability had been met with $\alpha = 0.9349$.

4.4.3 ANOVA and Tukey Pairwise Comparison Results EMG %MVC for VL, VM and RF

Since internal measurement reliability was displayed through both torque and absolute voltage data, %MVC recorded by EMG electrodes can now confidently be examined and analyzed. One-Way ANOVA was conducted for VL %MVC data, VM % MVC data and RF % MVC data for all 6 modalities tested: the TUG, FTSTS, SCPT, kBox, dynamometer concentric and dynamometer eccentric. Each ANOVA tested if the level/means of muscle activation were significantly different (higher or lower) from one another. The results of these tests are listed below.

The one-way ANOVA conducted for %MVC of VL activation between all six modalities displayed that there was a difference in %MVC muscle activation at the significance level $p < 0.05$ for the six exercise conditions [$F(5, 144) = 2.91$, $p = 0.016 < 0.05$]. This demonstrates there is a significant difference of means of muscle activation, expressed in %MVC, between the TUG, FTSTS, SCPT, kBox, dynamometer concentric, and dynamometer eccentric movements for the vastus lateralis muscle. The model summary displayed a $R^2 = 9.18\%$, meaning that 9.18% of the variance was explained by the modalities.

The above one-way ANOVA conducted displayed a difference of muscle activation between the six modalities for the VL. A Tukey post hoc test was conducted for the VL to test each of the conditions against one another to determine which means were significantly different from the six modalities.

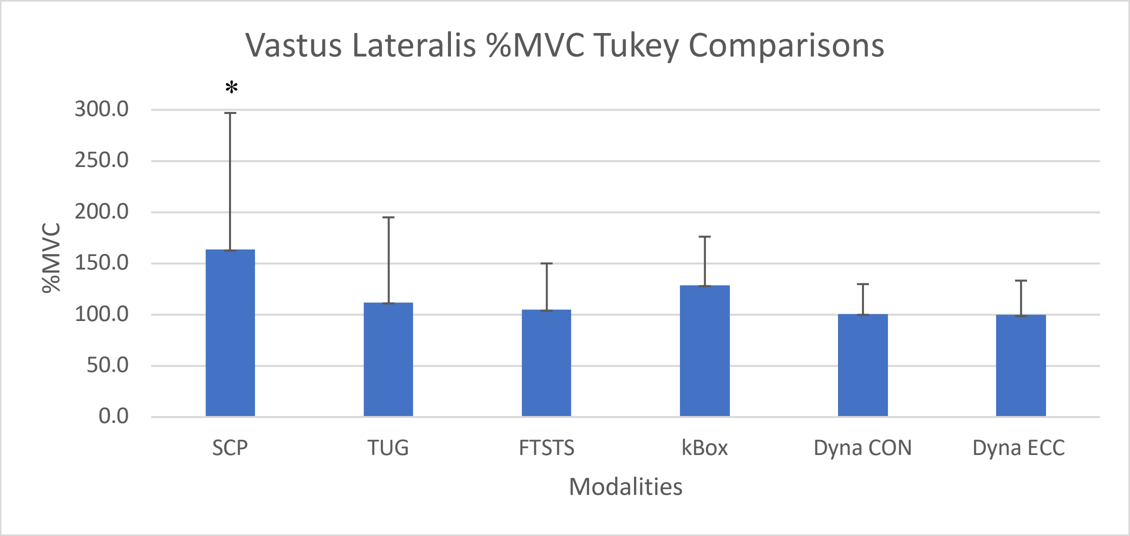


Figure 8: Tukey Pairwise comparisons Findings for Vastus Lateralis %MVC

* = different than all other modalities

Tukey pairwise comparison for the vastus lateralis showed the mean score for the SCPT test (163.5 ± 133.4 %MVC) is significantly different from the %MVC mean of the FTSTS test (104.8 ± 45.22 %MVC), $p = 0.048 < 0.05$, from the mean of the concentric dynamometer test (100.77 ± 29.02 %MVC), $p = 0.033 < 0.05$, as well as the mean of the eccentric dynamometer test (99.67 ± 33.50 %MVC), $p = 0.028 < 0.05$. The FTSTS (104.8 ± 45.22 %MVC), dynamometer concentric (100.77 ± 29.02 %MVC), and dynamometer eccentric (99.67 ± 33.50 %MVC) were not statistically different from one another. The kBox test (128.81 ± 47.30 %MVC) and the TUG test muscle activation (112.0 ± 83.0 %MVC) were not significantly different from any of the six modalities.

For the vastus medialis, muscle activation expressed as %MVC was also analyzed through a one-way ANOVA. The ANOVA displayed a difference of muscle activation (%MVC) at the significance level $p < 0.05$ for the six exercise modalities [$F(5,144) = 3.14$, $p = 0.01 < 0.05$]. The model summary produced displayed a $R^2 = 9.82\%$, indicating that 9.82% of variance in %MVC recordings was explained by the various modalities.

The above one-way ANOVA conducted displayed a difference of muscle activation between the six modalities for the VM. A Tukey post hoc test was conducted for the VM to test each of the conditions against one another to determine which means were significantly different from the six modalities.

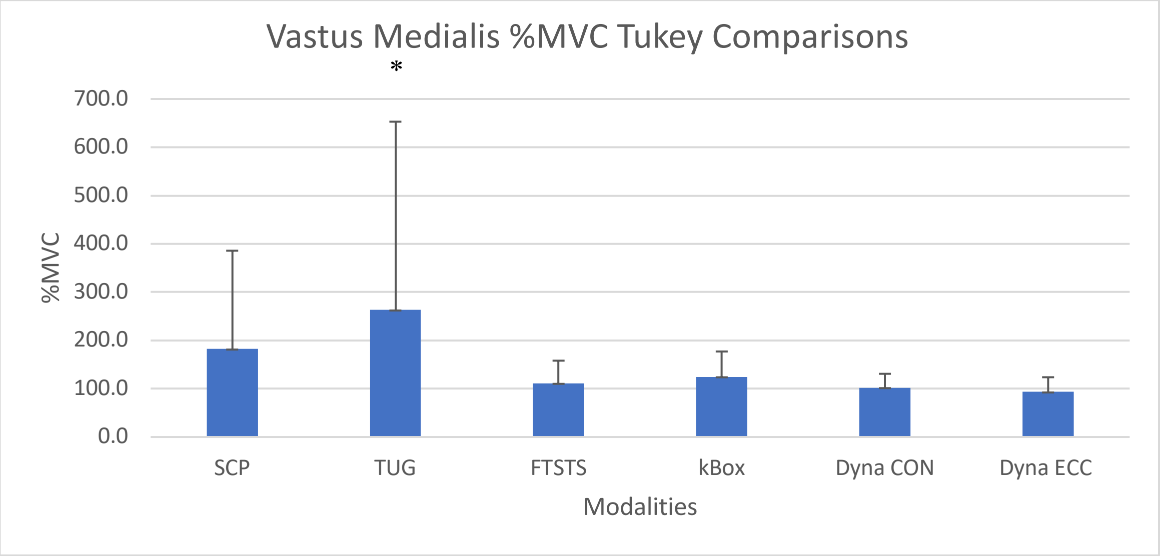


Figure 9: Tukey Pairwise Comparison Findings for Vastus Lateralis %MVC
* = different than all other modalities

Tukey pairwise comparison for the vastus medialis showed the mean score for the TUG test (263.00 ± 390.00 %MVC) is significantly higher and different from the mean of the FTSTS test (111.13 ± 46.98 %MVC), $p = 0.044 < 0.05$, from the mean of the concentric dynamometer test (102.15 ± 28.47 %MVC), $p = 0.032 < 0.05$, and the mean of the eccentric dynamometer test (93.33 ± 30.47 %MVC), $p = 0.02 < 0.05$. The FTSTS test (111.13 ± 46.98 %MVC), the concentric dynamometer test (102.15 ± 28.47 %MVC), and the eccentric dynamometer test (93.33 ± 30.47 %MVC) were not significantly different from one another. The SCPT test (182.10 ± 203.7 %MVC) and the kBox test (124.70 ± 52.4 %MVC) demonstrated muscle activation means were not significantly different from any of the six modalities.

For the rectus femoris, muscle activation expressed as %MVC was analyzed via a one-way ANOVA. The ANOVA identified that there was a difference of mean muscle activation (%MVC) at a significance level of $p < 0.05$ for all six modalities [$F(5,144) = 11.37$, $p = 0.00 < 0.05$]. The model summary produced displayed a $R^2 = 28.31\%$, indicating 28.31% of %MVC variance can be explained by the various modalities.

The above one-way ANOVA conducted displayed a difference of muscle activation between the six modalities for the RF. A Tukey post hoc test was conducted for the RF to test each of the conditions against one another to determine which means were significantly different from the six modalities.

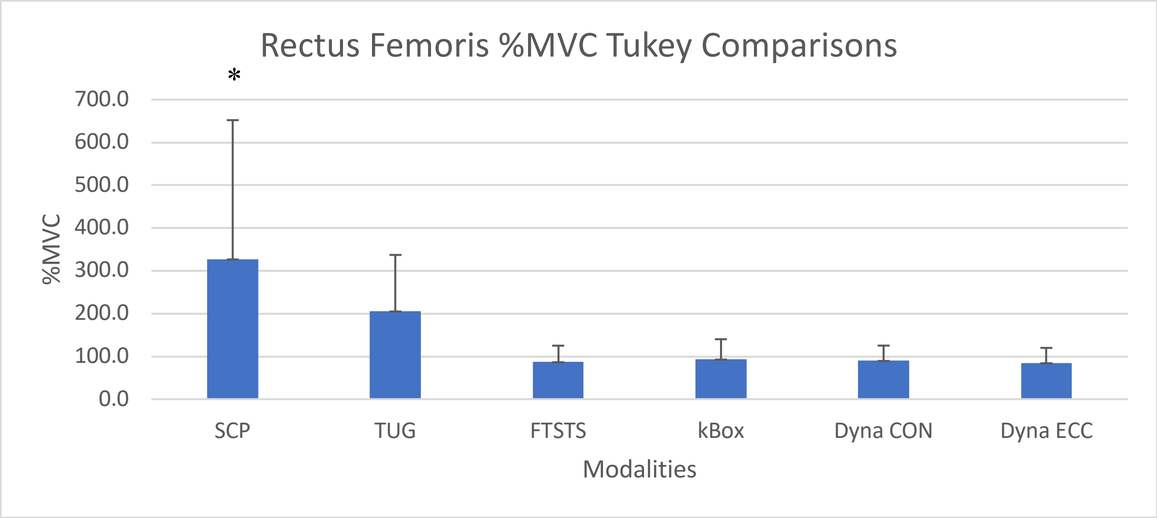


Figure 10: Tukey Pairwise Comparison Findings for Rectus Femoris %MVC
*= different than all other modalities

Tukey pairwise comparison for the rectus femoris showed the mean score for the SCPT (327.50 ± 324.6 %MVC) has a significantly different mean from the %MVC mean of the TUG test (205.90 ± 131.2 %MVC), $p = 0.044 < 0.05$, from the mean of the kBox test (93.55 ± 46.57 %MVC), $p = 0.00 < 0.05$, from the mean of the dynamometer concentric test (90.31 ± 34.87 %MVC), $p = 0.00 < 0.05$, from the %MVC mean of the FTSTS test (87.27 ± 37.73 %MVC), $p = 0.00 < 0.05$, and the mean of the dynamometer eccentric test (84.91 ± 34.96 %MVC), $p = 0.00 < 0.05$. The TUG, kBox, dynamometer concentric, dynamometer eccentric, FTSTS are not significantly different from one another.

When observing Tables 8, 9 and 10, it is noted that the SCPT is consistent across muscle groups for expressing high mean values for levels of muscle activation, expressed at %MVC. It is also consistent across tables that both the concentric and eccentric dynamometer tests display lower mean values for levels of muscle activation for all muscle groups.

4.4.4 One-way ANOVA Results for Muscle Oxygenation Data (%TOI)

One-way AVONA was conducted for %TOI data collected from the NIRO-200X for the vastus lateralis muscle. Data from the first repetition was used for dynamometer eccentric movement, dynamometer concentric movement, dynamometer isometric movement and kBox eccentric movement. The one-way ANOVA was conducted to determine if there was a difference in means between repetition one %TOI values between these four movements. The

ANOVA displayed that there was no significant difference of mean muscle oxygenation, expressed as %TOI, at a significance level of $p < 0.05$ across the 4 modalities $[F(3,100) = 2.47, p = 0.066 > 0.05]$. Therefore, this displayed that repetition one recordings showed no different deoxygenation in any of the four tests conducted.

Chapter 5: DISCUSSION

5.1 Introduction and Study Aim Review

This study aimed to determine 1) the relationship and physiological correlates between kBox flywheel squat torque and power and isokinetic dynamometer knee extension torque and power, 2) if the kBox measurements were more predictive of functional performance, and 3) if the above modalities investigated could be further explored through select physiological parameters (muscle oxygenation and electrical activity) in active seniors. For objective 1) we found that the kBox and the isokinetic dynamometer measured outputs were highly correlated, further displaying the kBox as an effective tool in recording physiological measures. For objective 2) we found that although both the kBox and isokinetic dynamometer showed promise for predicting functional performance measures, the dynamometer was significantly better in predicting functional performance than the kBox. For objective 3) we found no muscle oxygenation differences between kBox and Dynamometer tests and we found similar muscle activation via EMG across all modalities, suggesting all participants were completing tests at 100% perceived maximal effort.

5.2 Findings of Isoinertial kBox and Isokinetic Dynamometer Comparability (Hypothesis 1)

5.2.1 Agreement of Kbox and Dynamometer Outputs

As previously stated, the isoinertial kBox flywheel device has been used in a young, strength trained population (Maroto-Izquierdo et. al., 2017, Hoyo et. al., 2016, Hoyo et. al., 2015). Although the popularity and usage of this device has grown in the young population, the validity and consistency of its measured outputs by the kMeter still needs to be determined and confirmed as there are conflicting results (Weakly et. al., 2019, Bollinger et. al., 2018). The features the kBox possesses, including the option for eccentric overload and all measured outputs highlights the importance of confirming measurements and validity especially in a senior population.

When examining the raw data outputs from the dynamometer and the kBox in table three, it is important to compare these outputs to see how our sample of participants compared to the general population. In a study conducted by Hruda et. al., 2003, a training regime to gain muscle power in older adults was assessed through the use of an isokinetic dynaometer. Participants were in long-term care homes between the ages of 75-94 years old (Hruda et. al., 2003). The peak torque found post-training regime was 81.9 N*m for eccentric, and 35.8 N*m for concentric (Hruda et. al., 2003). These values are much lower than the peak torque recorded for our sample, displaying the higher fitness and functional level. In another study conducted by Overend et. al., 2000, a group of older men in their 70's was compared to younger subjects for concentric and eccentric isokinetic exercise outcomes. The peak torque produced by this group concentrically was 111 N*m, and eccentrically, 178.9 N*m (Overend et. al., 2000). Although these values are closer to the values displayed in table 3, the values are still below the data displayed. Additionally, Overend et. al., 2000 used an all male group which may not be truly comparable to the participants of this study. Last, in a study conducted by Pincivero & Ito, 2003, a study conducted on young, healthy individuals tested knee extension and flexion torque differences between male and female subjects using an isokinetic dynamometer. In this study, raw dynamometer outputs can be viewed. Similar outputs to our data can be seen, with our data actually being a bit higher. This demonstrates that our select sample, through their vigorous strength and power training routine as they age, seemed to produce similar peak torque outputs to a younger population. This leads one to speculate that muscle strength and power have been maintained in our sample in comparison to the average older adult.

The dynamometer outputs used were concentric and eccentric peak power, peak torque, and rate of torque development. The kBox outputs compared were the concentric and eccentric peak powers, peak torques and average powers. As displayed in the table, all outputs were moderately to strongly correlated, with an intraclass correlation ICC (1,1) of 0.742 which confirms a strong relationship between measurement modalities. These correlations display good agreement between all measurements produced within the senior population tested. These results therefore extend research examining the appropriateness of using measures produced by the kMeter device of the isoinertial kBox flywheel in this population.

In addition to extending this hypothesis, our study is novel in the fact that a strong correlational relationship of measures has been determined within a senior population. This supports the concept that clinicians and researchers may be able to rely on the output of the kMeter app when utilizing the isoinertial kBox for a senior population. This finding furthers the possible capabilities and clinical application the kBox may have.

5.2.2 Applicability and kBox Assessment Potential

Isokinetic Dynamometers have been used for years to determine and "develop the strength, power and endurance of muscles surrounding joints and is clinically accepted to increase one’s functional capacity” (Computer Sports Medicine, 2006). The reliability and validity of these measures produced by the Dynamometer holds true in a senior population, highlighting its applicability and usage to the aging population and demonstrating why the dynamometer is known as the “gold standard”. In addition to developing profiles and assisting in rehabilitation, the Dynamometer has been used in a senior population to determine functional performance and other physical parameters (Ford-Smith et. al., 2001, Suzuki, et. al., 2001, Moura et. al., 2020).

The outputs measured in this study by the dynamometer, as listed previously, are critical when determining functional performance in seniors. As demonstrated by Han & Yang, 2015, a dynamometer was used to determine the risk of falling in the elderly. This study concluded that muscle power determined by the dynamometer is crucial when determining fall potential and therefore provides insight into one’s functionality (Han & Yang, 2015). As demonstrated, the kBox peak and average power measurements highly correlated to that of the dynamometer and therefore, one can conclude that the kBox has such potential of predicting falls in the elderly.

Additional studies have been conducted demonstrating the potential of predictability and evaluation the dynamometer has in a clinical and rehabilitation setting. Dvir, 2014, states that the most well established and relevant outcome parameters of the dynamometer is the peak torque. Ellenbecker & Davies, 2000, highlights the importance that isokinetic training and testing has for thorough evaluations and rehabilitation programs. These are only some examples of how dynamometer measures have been well established, and well related to all demographics and co-morbidities in the wide-spread population. These examples not only demonstrate the applicability of the dynamometer but display the potential the kBox may possibly have in future clinical settings. Due to the high correlations and the strong associations shown by the kBox when compared to the dynamometer, one can speculate that the kBox may be useful when measuring lower extremity multijoint power and functional performance.

Not only can the kBox be a possible alternative measure, it may soon be the complementary choice due to overcoming the limitations of the dynamometer. The kBox is much less expensive than the dynamometer, increasing is accessibility, usage, diagnosis and treatment potential. Second, the kBox is much smaller than the dynamometer and therefore is not limited in transport again, increasing accessibility and usage. The last limitation the dynamometer poses is the knee extensor movement in comparison to the squat conducted by the kBox. This limitation has yet to be explored and will be done so below.

5.2.3 Single-Joint vs Multi-Joint Measurements

It was known that outputs the dynamometer measured would be limited to torques around one joint (the knee), in comparison to the multi-joint squat conducted on the kBox. This has yet to still be explored in relation to functional predictability. Most or all dynamometer measurements, whether it be an elbow, knee, hip, etc. are all conduct through single joint measures (Computer Sports Medicine, 2006). This is done to isolate the muscles of interest and these measures have been proven effective and accurate in various tests (Flanagan & Salem, 2005, Hayden et. al., 2017, Schulz et. al., 2008). The kBox however, uses multi-joint movements, and as explored earlier in the literature review, may be more applicable when assessing and predicting physical function in seniors.

When looking at the correlations produced, it is demonstrated that although these two movements are fundamentally different, the measured outputs are in agreement. This is an interesting finding as it displays both single joint and multi-joint evaluations may be valid methods when assessing outcomes such as muscle strength, power, torque and rate of torque development. The fact the measured outputs correlate give evidence that although these methods are different, each may be utilized in the future based upon budget, location, and other considerations that may come to light. Although the correlations are considered moderate to good, it is noted the agreement of measures means solely that the kMeter of the kBox is a valid form of measurement and does not truly speak to the debate regarding single joint vs multi-joint movements. When examining the limitations either single-joint vs multi-joint movements may have predicting physical function in seniors, further investigation is required. That is why the linear regression was performed on these measured outputs, in order to determine which factor(s) may be the most predictive of functional performance in a senior population.

5.3 Findings of Functional Ability Predictability (Hypothesis 2)

5.3.1 Dynamometer more predictive of Functional Performance

The correlations displayed in tables 6 and 7 demonstrate both the kBox and Dynamometer displayed similar agreement of measured outcomes with the TUG, FTSTS and SCPT. These findings were significant with no great difference between the Dynamometer and kBox correlations with the functional tests, respectively. Due to the fact that the isoinertial kBox and isokinetic Dynamometer displayed moderate to good correlations in the first hypothesis, it was expected that the correlations with the functional tests would also be similar. Not only did the kBox measurements correlate with the "gold standard" Dynamometer, but also showed similar correlations with functional tests displaying how these measurements may be furthered into a clinical setting.

In addition to performing Pearson's correlations, the multiple linear regression provided insight into which measured Dynamometer or kBox parameter(s) may be most predictive of functional performance in seniors. When examining Table 8, it is noted that the key factors are weight, concentric peak torque of the dynamometer, and concentric peak torque of the kBox. The concentric peak torque of the dynamometer was significant in two of the functional tests (TUG and SCP) whereas the concentric peak torque of the kBox was only significant in one of the functional tests (FTSTS). This is evidence the Dynamometer was more predictive of functional performance than the kBox. These findings speak to the second hypothesis of this study. It was hypothesized the kBox would be greater in predicting functional performance due to multi-joint movements being similar to daily activities, yet the findings do not support this. Rather, concentric peak torque of the dynamometer seems to be the greatest predictor of functional performance.

These findings further the concept of the dynamometer being the "gold standard" when assessing muscle function and developing a profile around a single joint. The dynamometer may be more predictive due to the reliability and validity of its measures, since the dynamometer can control for resistance, angular velocity, and determining ROM while measuring muscles of interest (Computer Sports Medicine, 2006, Habets et. al., 2018). By controlling these variables, the dynamometer removes external errors that the kBox cannot control for. This adds to over 20 yeas of clinical research and over 1000 published studies of supporting evidence of the capabilities the dynamometer possesses (Computer Sports Medicine, 2006, Drouin et. al., 2004, Habets et. al., 2018, Webber & Porter, 2010).

Separate to the isokinetic dynamometer and isoinertial kBox outputs assessed for predictability of functional performance, weight (kg) was also found to be a significant predictor in the forward stepwise multiple linear regression. This is not suprising as body composition and body weight are directly related to muscle power and muscle strength which was examined in the literature review showing that this predicts and determines functional ability (Patino-Villada et.

al., 2020). Greater body weight due to muscle mass itself impacts functional ability and leads to greater power-generating ability, improving one's function (Patino-Villada et. al., 2020). Therefore, it is not suprising that for the population of this study, strength trained individuals, that their body weight would be largly based on musle. Preservation of muscle indicates maintenance of strength and power which is important as one ages (Bonder & Bello-Haas, 2018). Therefore, body weight directly impacts and therefore was found as a predictor of functional performance in this study.

Of all the variables measured in this study, peak torque was the most significant in both the dynamometer outputs and kBox outputs and deserves exploration. Muscle strength, muscle power and rate of torque development were all examined earlier in the literature review as to their significance in the prediction of functional ability. It was noted the rapid force generating capacity may be an independent contributing factor in predicting and assessing function in seniors (Osawa et. al., 2018, Driessche et. al., 2018). Both RTD and muscle power account for velocity of movement and were thought to be more predictive and important to examine in terms of function. An abundance of research supports the claim that muscle power is more important in predicting function than muscle strength (Evans W., 2000, Skelton et. al., 2002, Henwood et. al., 2008, Bean et. al., 2003, Reid & Fielding, 2012). In contrast to this evidence, our findings show that muscle strength was the greatest predictor of functional performance derived from the FTSTS, SCPT and TUG. This could be due to our select sample and characteristics of the individuals tested. Due to our subjects being highly active, strength trained older adults, it is possible that muscle strength and power have been preserved. Therefore, since muscle power decreases at a greater rate than muscle strength (Bonder & Bello-Haas, 2018), it may have not decreased as predicted by normal population standards. This means muscle power may therefore not be the greatest predictor of function due to the maintenance of power within our select sample. Our sample contained strength training adults which through their workout schedule and lifestyle, would have maintained muscle power more so than the average individual within this age group. A reason why RTD may not have been the greatest predictor was explored in a study conducted by Dvir 2014. In this study it was found that under dynamic conditions, RTD has greater interaction between the motor response and the recruitment process. This may result in a flutter in the torque curve and therefore possibly limit the reproducibility of the measurement, meaning that this will limit RTD as a relevant parameter (Dvir, 2014).

5.3.2 kBox Findings regarding Functional Performance

As previously stated, this study found the kBox has less potential of predicting functional performance than the isokinetic Dynamometer. One possible explanation for this outcome may be the various inertia loads the isoinertial kBox flywheel can utilize during eccentric overload training. It has been noted throughout literature that the most advantageous, most effective inertia load has yet to be identified in terms of training benefits as well as the effects it may have on the measurements of power, force, strength, percentage of overload, etc. The inertia load used for the current sample population was the mid-range of 0.05kg*m^2. In a study conducted by Sabido et. al., 2018, handball players tested the effects various inertia loads had on concentric peak power and eccentric peak power during the squatting motion. The inertia loads explored were 0.025kg*m^2, 0.050kg*m^2, 0.075kg*m^2 and 0.100kg*m^2. This study found that the lowest inertia produced the greatest concentric peak power measurements whereas low to medium inertia produced the greatest eccentric peak power measurements. It was highlighted by Sabido et. al., 2017 to ensure participants performed three sessions to obtain a stable measurement from the flywheel during the squatting exercise. Our study is consistent with this recommendation and therefore furthers confidence into the measurements obtained. In addition to this study, two other recent pieces of literature have noted that the lowest inertia load seems to produce the best power outputs (Sabido et. al., 2017, Martinez-Aranda & Fernandez-Gonzolo, 2017). In both studies, multiple inertial loads were tested. From the studies noted, the lowest inertia seems to have the greatest effect on the power produced eccentrically and concentrically. It is also noted by Exxentric, AB, Sweden, 2019, the lowest inertia in combination with high speed results in the greatest power output. Since our participants used 0.050kg*m^2, it is possible we did not obtain the maximum power outputs of individuals, limiting our assessment of function. Although this conclusion can be speculated from previous literature, it may not be completely applicable in our findings. Most of the studies that examine various inertia loads use a young, strength trained population. Therefore, although assumptions regarding inertia load may be made, no conclusive results or explanation can be taken from these findings.

Another explanation as to why the kBox may not have been as predictive as the dynamometer is the possibility of errors in measurement. As mentioned before, the Dynamometer can control for velocity, resistance, and has a set range of motion (Computer Sports Medicine, 2006). The kBox does not have control over these variables. The mechanism of the squatting motion leaves room for inconcsistencies due to variances in both speed and range of motion. Researchers tried to control the range of motion participants had on the kBox by using timing gates to indicate the squat stance required, as mentioned in the methodology section. Although this precaution was taken, the total depth of the squat could not be controlled during the SPT. Speed is also determined by the specific user with each being instructed to be at maximal effort. Resistance can be unlimited throughout the whole squatting motion (Exxentric, AB, Sweden, 2019). All the factors listed, ROM, velocity and resistance will affect the outcome parameters measured and therefore the predictability of functional performance. The limitation of inconcsistencies and a more controlled environment when producing measurements is always strived for in experimentation to ensure valid and reliable results (Roberts & Priest, 2006). Due to the limitations of outside errors, this may have also contributed to the kBox not being as strong in the prediction of functional performance than the Dynamometer.

Lastly, what may also contribute to the results found was the familiarization of participants with the methods of the SPT protocol of the isoinertial kBox. It is important to ensure participants have sufficient familiarization sessions with the kBox to ensure comfortability and confidence when conducting the SPT. Bollinger et. al., 2018 conducted a study on the kBox 4 Pro with young, strength trained individuals. It was concluded that "those unaccustomed to a flywheel modality may require multiple testing sessions or a more thorough familiarization period to ensure accurate measures of power, force, speed and work" (Bollinger et. al., 2018). In addition to this study, the mechanical demands as well as the unusual methods of the SPT also highlight the importance of proper familiarization (Beato & Iacono, 2020, Hody et. al., 2019). Specifically, Beato & Iacono, 2020 state that a minimum of two to three familiarization sessions are required to become acquainted with this training method. With greater familiarization and a slow increase in intensity, one also avoids the muscle damage and soreness often associated with SPT training (Hody et. al., 2019). In addition to proper familiarization, the correct amount of testing sessions has been recommended to be three in order to obtain accurate measurements (Sabido et. al., 2018). For the study conducted, our participants were provided with two familiarization sessions, one in the first testing day and another on the second testing day. Also, a total of three trials were conducted when collecting data, following the recommendation set by Sabido et. al., 2018.

5.3.3 Further examination of Single-Joint vs Multi-Joint Movements

It is important to examine whether the single-joint evaluation tool (dynamometer) or the multi-joint evaluation tool (kBox) was more predictive of functional performance based on the information highlighted throughout the literature review. Due to the fact that the movements are different, the knee extension for the dynamometer and the squatting motion for the kBox flywheel, yet they both are predictive of lower body functional performance leads one to explore the reasons as to why one may be more predictive of functional performance than the other. The examination regarding single-joint vs multi-joint movements can be expanded upon from section 5.2.3. In that section, the correlations demonstrated the movements measured produced similar correlations of power and torque, displaying the kMeter may be a valid form of measuring outputs in comparison to the dynamometer. To expand upon this investigation, the linear regression performed needs to be explored. The evidence in Table 7 demonstrates which factors were the most significant in predicting functional performance, as stated earlier. This also provides further insight into which method, single-joint or multi-joint, is a more predictable form of evaluation and which may be better suited to predicting functionality in a senior population. As demonstrated, the dynamometer was found to be significantly predictive in two of the functional tests whereas the kBox was found to be a significant predictor in only one of the tests. Therefore, single-joint dynamometer measured outputs were more predictive of functional performance for the TUG, FTSTS and SCPT than the multi-joint evaluation conducted on the kBox.

The one functional test in which the multi-joint evaluationwas more predictive was the FTSTS test, with the concentric peak torque from the kBox being most predictive. This result could be due to the close similarities between these movements. Researchers had predicted for hypothesis 2 that mutli-joint movement would be more reflective of functional performance due to the similarity of the movement. The FTSTS is the one functional test performed that was the most reflective of the squatting movement of the kBox. Therefore, this is promising as it reflects that the kBox produced measurements predictive of movements with that similar action. The concentric peak torque may have been more predictive than the eccentric peak torque on the kBox due to the FTSTS being limited concentrically. As stated previously, daily movements and traditional resistance training are limited concentrically (Gault & Willems, 2013; Maroto-Izquierdo et. al., 2017; Friedmann-Bette et. al., 2010). Due to the submaximal eccentric activation during the FTSTS, the eccentric kBox recording during eccentric overload would therefore not be the most reflective or predictive of this movement. Therefore, the concentric activation during the FTSTS and kBox test were the most similar, reflecting the similarity in movement. Last, the variance of body weight and speed may also have been limited throughout the similarity of the movement between the FTSTS and the kBox, leading to the kBox being more predictive of this movement than the dynamometer.

In all, these findings demonstrate that single-joint movements and multi-joint movements are both reliable forms of predicting functional performance (Schulz et. al., 2008, Hayden et. al., 2017, Schoenfeld & Contreras, 2012). Although the dynamometer may be more predictive of functional tests, the kBox results are still promising, demonstrating that majority of function was also predicted by this method. It was hypothesized that the multi-joint movement performed by the kBox would be more predictive due to the analogous movements required during functional tests. As stated previously, multi-joint training seems to be more reflective of activities conducted in daily life (Schoenfeld & Contreras, 2012) whereas single-joint evaluations are more useful when one is interested in isolating specific muscle groups. Yet the findings display both forms of evaluation were predictive of functional performance, speaking to both the validity and reliability of the dynamometer as previously described as well as the potential the kMeter has for future studies.

Due to the benefits of multi-joint training, as highlighted throughout the literature review, it is important to recognize the potential the kBox and kMeter may have in the future. Through implementing the SPT protocol, it was demonstrated the kBox is useful tool of power and force measurement and has now further demonstrated it has potential to predict function through a multi-joint evaluation. This provides clinicians with the option to perform future multi-joint evaluations of strength and power using the flywheel device.

5.4 Muscle Activation and Muscle Oxygenation Findings (Hypothesis 3)

5.4.1 Muscle Activation Differences

It was predicted the %MVC and muscle activation would be similar between the kBox, the FTSTS, SCPT and the TUG due to the similar mechanics which require multi-joint movements. The dynamometer was predicted to not be as similar due to the isolation of muscles and the single-joint evaluation. As discussed in the results section, the ANOVA performed for each muscle group displayed significant differences of %MVC between the modalities.

Therefore, a Tukey post Hoc test was conducted for each muscle group as shown in Figures 8, 9 and 10, respectively. For the VL, Figure 8, it is observed that the mean %MVC for the FTSTS, concentric dynamometer, eccentric dynamometer, kBox, and TUG showed no significant difference from one another. The only test that displayed a significant mean %MVC difference for the VL was the SCPT. For the VM, Figure 9, it is observed that the mean %MVC for the SCPT, kBox, FTSTS, concentric dynamometer and eccentric dynamometer showed no significant difference from one another. The TUG mean %MVC was highest for the VM. Last, for the RF, Figure 10, it is observed that the mean %MVC for the TUG, kBox, FTSTS, concentric dynamometer and eccentric dynamometer showed no significant difference from one another. The only test that displayed significant mean %MVC was the SCPT. The %MVC for the SCPT expressed high mean values across muscle groups where there were no significant differences between the rest.

In summary, Figure 8, 9, and 10 display similar mean %MVC for a majority of the tests conducted. Due to the fact there were no significant differences found between most of the tests, it can be noted that muscle activation levels may have been similar throughout modalities including the isoinertial kBox and the isokinetic dynamometer. During the conduction of all tests, participants were instructed to be at their maximal effort. Since the %MVC is similar for most modalities, this can support the concept that each participant may be exerting similar effort/force, perceived as maximal, when performing each task. Similar to our findings, the study by Alkner et. al., 2000, found no significant difference in EMG recordings between modalities tested when examining the VL, VM and RF. It was concluded the EMG/force relationship for quadricep muscles appeared to be similar in each action tested (Alkner et. al., 2000). Since participants conducted each test with 100% maximal effort, the EMG outputs were similar when processed and examined. This furthers the indication that participants were exerting maximal effort when conducting the various tests of this study due to consistent testing.

The findings presented in Figures 8, 9 and 10 do not support the predicted hypothesis regarding muscle activation. The kBox and the Dynamometer did not display significantly different mean %MVC and the kBox muscle activation did not relate greater to the functional tests than the dynamometer. As stated previously, there have been many conflicting reports regarding eccentric and concentric actions and the sEMG recordings they elicit. In a study conducted by Norrbrand et. al., 2010, when comparing traditional resistance training and eccentric overload flywheel training sEMG, higher muscle activity was detected in the eccentric overload training. In contrast to this, other studies claim that EMG activity is less during eccentric movements due to multiple physiological effects (Aagaard, P., 2016; Ebenbichler et. al., 2017). Specifically, the University of Denmark highlights three key physiological aspects that may attribute to eccentric actions eliciting less muscle activation: first, pre-loaded tension results in less muscular demand, second, there are distinct neural patterns of activation for eccentric and concentric actions with sites of inhibition of eccentric pathways in the CNS and finally, the metabolic efficiency displayed may also influence the motor units recruited (Aagaard, P., 2016). The findings of this study cannot support these conceptions. No significant differences were found between kBox sEMG, concentric dynamometer sEMG or eccentric dynamometer sEMG. Although the kBox elicited greater sEMG for each muscle group, the total reading could not be split into concentric or eccentric actions and therefore one cannot conclude where the greatest or least activation was elicited. Therefore, this study adds to the ambiguity regarding eccentric actions and EMG readings, highlighting the need for future studies and deeper investigation, especially regarding eccentric actions due to the physiological potential and advantages it may hold.

5.4.2 No Variation in Muscle Oxygenation

It was predicted the kBox would elicit greater muscle deoxygenation due to the demands of the kBox SPT in comparison to the isokinetic dynamometer. The findings show that when the ANOVA was conducted between the repetition one %TOI values of the four modalities described, no significant deoxygenation difference was found between the groups. Since no significant difference was found between kBox and dynamometer test regarding muscle activation, having no significant difference in deoxygenation correlates since these two factors are so closely related physiologically.

It was speculated the kBox would display greater deoxygenation due to the effort required for the SPT and the multi-joint movement in comparison to the single-joint movement elicited by the dynamometer. Although it is perceived to require a greater effort during kBox SPT protocol, the oxygen demands do not reflect this. This could be due to the nature of eccentric contractions and the altered energetics in muscle fibers resulting in the capability of being metabolically efficient in comparison to concentric contractions. It has been found that eccentric contractions activate fewer muscle fibers than concentric therefore resulting in lower

ATP requirements (Ryschon et. al., 1997). Additionally, further studies have confirmed there is smaller oxidative metabolic demands for a greater torque output and therefore also suggest eccentric muscle efficiency (Muthalib et. al., 2010). Furthermore, the metabolic efficiency of eccentric contractions can also be attributed to the unique activation strategies by the nervous system which are different than concentric, as noted in the previous section (Enoka R. M., 1996, Ebenbichler et. al., 2017, Aagaard, P., 2016). Another variable to consider is the increased intramuscular pressure eccentric contractions elicit, possibly preventing oxygen supply to the muscle and therefore resulting in a lesser decrease in %TOI (Muthalib et. al., 2010). The ability of the kBox SPT to elicit greater changes in muscle oxygenation demonstrates one way in which greater muscle hypertrophy may be observed. As stated previously, the greater changes in muscle oxygenation results in the enhancement of factors that initiate and stimulate hypertrophy (Schoenfeild et. al., 2017).

5.5 Summary

In summary, responses to the three hypotheses set at the beginning of this study have been found and provide insight into the equipment used in function predictability and maintenance of lower body strength and power. The findings discussed in section 5.2 provide evidence supporting the first hypothesis. The isoinertial kBox flywheel device displayed a moderate/strong relationship in comparison to the isokinetic dynamometer as high Pearson's correlations were found. This demonstrates the isoinertial kBox flywheel can be used with confidence in producing measures of power, torque, rate of torque development and percent overload.

The findings discussed in 5.3 provide evidence that did not support the second hypothesis. Although the correlations between the dynamometer and functional tests, and correlations between the kBox and functional tests were very similar, the linear regression demonstrated that the isokinetic dynamometer was more predictive of the three functional tests than the isoinertial kBox. This demonstrates the "gold standard" classification the dynamometer has been assigned. The kBox was still found predictive of two of three functional test which are promising results. The investigation into the possibility of these findings in section 5.3.2 display room for growth regarding the kBox and its measurement potential. Additionally, the importance of eccentric overload which can be elicited by the kBox cannot be overlooked. The benefits and implications SPT training can pose on a senior population is crucial. Eccentric overload can result in greater force and power, greater muscular adaptations and hypertrophy, with decreased metabolic demand and decreased cardiovascular demand (Bonder & Bello-Haas, 2018, Insner-Horbeti et. al., 2013, Gault & Willems, 2013, Hedayatpour & Falla, 2015, LaStayo et. al., 1999, Roig et. al., 2010). In addition to the benefits of eccentric overload, the kBox flywheel demonstrated its potential in predicting functional performance.

With the findings in sections 5.2 and 5.3, it can be noted that the isoinertial kBox flywheel device holds great potential for future testing. It was demonstrated to be a useful form of measurement when compared to the isokinetic dynamometer, as well as be predictive of functional performance. The kBox therefore has demonstrated to overcome the limitations set forth by the dynamometer; it is not as costly, it can be transported and the multi-joint evaluation is a valid form of testing, and overall has increased accessibility. Therefore, this study supports the isoinertial kBox flywheel being used in future research to determine its greater potential for a clinical as well as training setting. The importance of this research and future investigation will assist in the maintenance of lower body strength and power of Canada's population by offering choice of equipment used for functional assessment as well as the continuing investigation into the benefits of SPT training.

Lastly, the findings in 5.4 provide physiological insight into the similarities and/or differences between the modalities tested and the three functional tests performed. These findings did not support the third hypothesis. Muscle activation remained relatively similar across the modalities and no greater deoxygenation was found during the kBox SPT test and the isokinetic dynamometer tests. The reasons why these results were found were discussed in 5.4 and further the need for more conclusive investigations. Through understanding these physiological measurements, one may gain further insight into the mechanisms behind eccentric overload and therefore understand the benefits its provides for seniors on a physiological level.

Overall, the evidence found of the isoinertial kBox flywheel device supports its strong relationship of measures, displaying potential to predict functional ability and therefore may be a future option to assess mulitjoint power and functional performance instead of the isokinetic dynamometer in a clinical setting. The physiological findings of muscle activation and muscle oxygenation provide insight into the mechanisms of eccentric actions but also add to the conflicting research previously noted. Due to the great potential the kBox holds as well as the capability of eliciting eccentric overload, future research is required to assist Canada's senior population in healthy aging.

5.6 Limitations

There are both general and specific limitations of this study. The general limitations noted of this study include the population examined, as well as the protocols tested. The individuals used for this experiment were strength-trained, very active, and physically fit individuals. Due to this select group of individuals, findings are difficult to translate to the general population. Another limitation is related to the specific protocol that was used during the kBox flywheel sessions. The kBox SPT requires individuals to be very familiar with the kBox. The eccentric overload can put strain/stress on joints that may be absent when conducting traditional resistance training. Therefore, this limits the population that can be tested in future studies as well as the individuals that use the kBox for training purposes. Additionally, as noted in section 5.3.2, the optimal inertia load has not yet been identified for various populations and comorbidities. Therefore, if this is investigated further, this might open the scope and range of people that can use the kBox in the future, whether it be in a training setting or in a clinical/rehabilitation setting.

A specific limitation noted during the study was the method in which muscle oxygenation (%TOI) was collected. The NIRO-200X was not wireless and therefore no deoxygenation data was collected for the three functional tests. This limited our scope and investigation into the physiology of these movements as well as the relation to both the SPT kBox flywheel protocol and the isokinetic dynamometer. The other specific limitation noted during the study was the process of analysis for the sEMG data. The highest amplitude of interest for the functional tests could not be narrowed down to a specific movement. Therefore, although peak amplitudes were taken for analysis, the point at which these peak amplitudes occurred cannot be singled out limiting the extrapolation of our findings. In addition to the analysis method used for the EMG, the confidence of these findings is also limited due to the sample size of participants. The sample size was determined by the power needed for the functional performance outputs to be predicticed by strength and power measurements, the key research question of the study. This power/sample size calculation therefore left researchers underpowered to truly detect EMG changes. Therefore, this also limits the confidence and subsequent conlcusions one can take from the EMG findings.

5.7 Future Research and Recommendations

Future research is always necessary when examining a novel product such as the isoinertial kBox flywheel device. Throughout the research process, aspects have been identified where future research is required in order to gain further insight into its capability and applicability in a training or clinical setting with senior populations.

Future research regarding the kBox flywheel and its capability within a senior population is necessary to further findings and understandings. Future research into the capabilities of the SPT protocol of the kBox flywheel device should examine a range of the general population with various physicality levels as well as comorbidities. Additionally, within the general senior population, future research should examine the effects the various inertia plates on the outputs of power, torque, rate of torque development, speed and percentage of eccentric overload (Exxentic, AB, Sweden 2019). This would provide insight into which inertia may be best fitted for the outcomes desired, whether it be power, torque or percent overload. Last, the exercise investigated throughout this research project was the squatting motion. Other movements using the eccentric overload protocol are possible need to be investigated in order to determine the effects this protocol has overall.

Other future research should examine whether training is measured by the kBox flywheel and test if responses to training are correlated to function. This would extent the kBox evaluation capabilities through applying it to a training regime. This would also assist in the senior population as various training regimes could be tested, relate to function and further knowledge regarding maintenance of muscle strength and power as one ages. Additionally, investigation into sex differences for inertia, power and force outputs and the SPT protocol is required to further understanding the possible differences and influence sex may have on these outcomes. This may be an important area to investigate in order to determine optimal eccentric training regimes for older adults.

Last, different training protocols and methods using the kBox need to be explored to see how this could apply to a senior population. Not only could the kBox be a potential evaluation tool, but it could also be used as a training regime for the aging population. Specific protocols for various muscle groups need to be investigated to find the protocol that is both effective and efficient.

5.8 Conclusion

Proper assessment of functional performance to assist with healthy aging that is cost effective, easy to access, and reflects daily activity is a growing importance in Canada's aging population. This study examined the different tools available to assess functional performance, provided evidence of which tool is more predictive of functional performance, and also provided insight into the physiological differences/similarities of modalities through muscle activation and muscle oxygenation measures. The results of this study provide information about the uses of both the dynamometer and the kBox, and specifically highlight the potential the kBox may have in assessing muscle outputs, such as power and strength, the use of eccentric overload in seniors, and finally, the application it may have in future clinical settings.

Although this is one of the first studies to examine the use of the isoinertial kBox in a senior population for its ability to predict functional performance, it will not likely be the last. The correlations the kBox exhibits with dynamometer measures, the ability to predict functional tests, and the similar physiological means all support the kBox's future potential and call upon further research. A door has been opened into the potential this equipment has, along with the benefits of eccentric overload. The importance and benefits of eccentric overload cannot be overlooked, especially for a senior population. When it comes to healthy aging, this may be a novel and unique method that could be accessed by all due to its cost-effective price and transportability and therefore, the isoinertial kBox may be one method that can assist with healthy aging of the Canadian population.

Chapter 6: CONCLUSION

This study had three goals. The first goal was to assess the isoinertial kBox flywheel relationship of its power and torque outputs in to the “gold standard” isokinetic dynamometer. The second goal was to determine if the kBox was more predictive of functional performance than the isokinetic dynamometer by comparing power and torque outputs to three functional tests. The last goal was to provide insight into the physiological mechanisms across all modalities examined through the use of muscle oxygenation (%TOI) and muscle activation (%MVC). The group examined contained athletic seniors, who were familiar with strength and power training with no comorbidities between the ages of 62 to 69 years old. These participants attended two separate testing sessions. The first testing session contained a standardized warm up, placement of both muscle oxygenation electrodes and EMG electrodes, a quiet standing trial, maximum voluntary contraction recordings, the completion of TUG, FTSTS, and SCPT, and finally, a practice session on the kBox flywheel device using SPT protocol. The second testing session contained the kBox SPT, and the dynamometer concentric, isometric, and eccentric tests.

The data collected and analyzed from the two testing sessions informed the study goals mentioned above. For the first goal, it was found the isoinertial kBox power and torque outputs were correlated with the power and torque outputs of the “gold standard” isokinetic dynamometer. These finding support the first hypothesis and add to the growing literature supporting the usefulness of the isoinertial kBox measures. For the second goal, it was found that the isokinetic dynamometer was more predictive of functional performance than the kBox, although the kBox showed promise as well. For the last goal, no difference in muscle oxygenation was found between modalities and similar muscle activation was found across all activities. Although this does not support our third hypothesis, it demonstrates that 100% perceived maximal effort was given during each modality by participants.

The main take-away from this study is the potential the isoinertial kBox demonstrated in measuring various outputs and predicting functional performance. The power and torque outputs being highly correlated with the dynamometer demonstrate the validity of its measures, therefore becoming a potential alternative tool than the dynamometer if desired. Second, the potential in predicting functional performance was promising and further investigation is required. Last, as highlighted throughout the paper, the SPT protocol utilized by the kBox and its benefits for seniors cannot be overlooked and deserve additional attention. Overall, due to the benefits of eccentric exercise for seniors and the measuring capabilities displayed by the kBox in this study, this is a promising tool for future use in a senior population for assisting in healthy aging, and further investigation is absolutely necessary.

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Appendix A

Research Study Consent Form

PARTICIPANT INFORMATION AND CONSENT FORM

Eccentric Squat Loading as Means of Assessing Function in Seniors

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INTRODUCTION

You are invited to take part in a research study because you are an adult within the age range of 55-85 years old, who is familiar with traditional resistance training and trains using the squatting motion.

Your participation is voluntary. It is up to you to decide whether or not you wish to take part. If you wish to participate, you will be asked to sign this form. If you do decide to take part in this study, you are still free to withdraw at any time and without giving any reasons for your decision.

Please take time to read the following information carefully. You can ask the researcher to explain any words or information that you do not clearly understand. You may ask as many questions as you need. Please feel free to discuss this with your family, friends or family physician before you decide.

WHY IS THIS STUDY BEING DONE?

This research study is investigating the ability of a new system of loading back squats called a flywheel eccentric overload system, to predict functional performance in seniors. An eccentric overload is a load (resistance and power) that is greater on the lowering phase of squatting than you can produce on the lifting or raising phase. As well, a comparison between this flywheel eccentric overload system and the more commonly used dynamometer will be made to examine its' validity. Finally, physiological parameters including the maximum amount of oxygen used (VO2), muscle oxygenation, muscle strength, muscle power, and muscle activation will be measured through the various forms of exercise. The information from this study will help the researchers understand if the flywheel eccentric overload system can predict functional performance and if it is an economical option when measuring strength and power outputs. The physiological parameters measured will provide insight into these findings.

WHO IS CONDUCTING THIS STUDY?

This study is being conducted by Dr. Scotty Butcher, a faculty member in the School of Physical Therapy at the University of Saskatchewan as well as Kelsi Kowalchuk, a master's candidate, in the Department of

Health Sciences at the University of Saskatchewan. The researchers and the University of Saskatchewan are not being paid to conduct this study, although the company who made the equipment (Exxentric AB, Bromma, Sweden) has donated the equipment on loan to the researchers.

WHO CAN PARTICIPATE IN THE STUDY?

You are eligible to participate in this study if you are between the ages of 55 to 85 years old and have been resistance training regularly (minimum of three times per week) for the past three months. In addition to this, you must have been training the squat exercise at minimum once per week during your resistance training program. If you have a significant medical concern (heart disease, lung disease, diabetes, or bone or joint problem) ***that would limit your ability to perform back squats***, you cannot participate in this research study.

The testing sessions will be booked within two weeks of your initial contact with the researchers. If you are unable to schedule a data collection session during this time, it is possible that you may not be able to participate in the study.

WHAT DOES THE STUDY INVOLVE?

You will be asked to attend two testing sessions at the School of Rehabilitation Science Exercise Lab at the University of Saskatchewan. The fist session will last approximately 1 hour 30 minutes and the second session will last approximately 60 minutes. The total time commitment is therefore 2 hours, 30 minutes. We ask that you refrain from doing any heavy resistance training sessions for 48 hours prior to your scheduled testing session. Please bring appropriate footwear for squatting and please wear shorts.

You will progress through the following phases of testing; initial screening conducted by phone or email, followed by two separate visits. The first visit includes the completion of three functional performance tests, followed by a practice session on the kBox flywheel device and dynamometer. The second session involves the 5RM (repetition maximum) eccentric overload tests on both the kBox and dynamometer. Testing sessions will be scheduled at least 24 hours apart and will be conducted in random order.
First Visit:

i) Informed Consent – You will be required to read and sign the consent form at the bottom of this document. The consent form will be provided for you by the researcher by email or mail prior to the initial visit or upon arrival.
ii) Screening (second phase) – You will be asked to complete a Get Active Questionnaire, which is screening form that will assist the researchers in determining your eligibility for the study. You may be asked some questions about your answers for clarification.
iii) Initial measurements – Age, weight, height, and experience with training will be recorded.
iv) Warm-up – You will be required to warm up for squatting on the kBox and knee extensions on the dynamometer. This would include any squatting exercise you require to feel warmed up. In addition, you will be allowed to complete any mobility work that you would typically complete prior to squatting/working out.
v) Functional Performance Tests – After the researcher demonstrates and explains the procedures for the three functional performance tests; 1) the time-up-and-go test (TUG), 2) the five-time-sit-to-stand (FTSST), and 3) the stair-climb-test (SCPT), you will be fitted with the electrodes that measure the physiological parameters outlined previously. You will be required to perform all three tests, in random order. The TUG tests involves you sitting in a chair, standing, walking three meters, turning and walking back to sit in the chair. The FTSST tests requires you to rise from a chair five times. The SCT requires you to climb up and down a flight of stairs. All tests will be timed.
vi) kBox 5RM Practice Testing – After the researcher demonstrates and explains the procedures for the kBox eccentric overload, you will be fitted with a harness that will attach to the cable of the kBox. You will be required to perform two initial repetitions to build momentum, then five

repetitions where you will be asked to exert approximately 80% effort on the raising, immediately squatting to a quarter squat, and letting the load pull you down to approximately 90°. You will be given a 5 minute rest, then will repeat the practice trial for 2+5 more repetitions.

vii) Dynamometer Practice Testing – After the researcher explains the procedures for the dynamometer 5RM test, you will be asked to take a seat in the chair. Your individual settings will be adjusted and recorded for the following session. Once the dynamometer has been personalized to your settings, the supervisor will raise your leg to a fully extended position. You will then be instructed to push against the pad, and resist the downwards movement. This will be done for a total of 5 trials. You will be given a 5 minute rest, then will repeat the practice trial for 2+5 more repetitions.

Second Visit:
kBox Eccentric Overload 5RM Test:

i) Warm up – You will be required to warm up using the same procedures and loads as in the First Visit.
ii) kBox Power Test – You will be fitted with the same harness as in the practice test in the First Visit. You will also be fitted to the electrodes as done for the functional performance tests in the first session. These electrodes will measure muscle oxygenation and muscle activation during this exercise. The procedures for these tests are exactly the same as in the First Visit, except that you will be asked to perform the five testing repetitions at 100% of your effort on the raising phase of the squat.
iii) You will be given a 3 minute rest and will repeat the two momentum repetitions and the five 100% effort repetitions for a total of three sets.

5RM Dynamometer Test:

i) Warm up – You will be required to warm up using the same procedures and loads as in the First Visit.
ii) 5RM Test – You will be seated in the dynamometer as in the practice test, as your specific settings would have been recorded. You will also be fitted with the electrodes as done for the functional performance tests in the first visit. The procedures for these tests are exactly the same as in the first visit, except that you will be asked to perform the five testing repetitions at 100% of your effort, resisting the downwards motion.

At any point during the testing session, the researcher may take video and/or pictures. With your permission, the researchers would like to use video and picture data for educational purposes to help explain the research protocol and the results. Anything that may identify you in a video or photo (i.e. your face) will be concealed to maintain anonymity. You can choose to agree to have video and/or pictures taken of you at the end of this consent form. If you choose not to have video and/or pictures taken, you are still able to participate in this research study.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

If you choose to participate in this study, there will be no direct benefit to you. It is hoped the information gained from this study will allow rehabilitation, strength and conditioning, biomechanics and ergonomics professionals to use a practical method of testing heavy loading using an overload on the lowering phase. In addition, if this tool proves to be valid and reliable, future research and training methods using it will be explored.

ARE THERE POSSIBLE RISKS AND DISCOMFORTS?

If you choose to participate in this study, you will be exposed to risks associated with performing heavy resistance training. These risks include:

- *Acute muscle and/or joint injury*
- *Cardiovascular risks associated with short-term elevations in blood pressure and heart rate*

- *Dizziness*

To mitigate the risk of injury and soreness, practice trials and progressive warm ups are employed as in standard practice. In addition, all testing will be supervised by researchers trained in the methodology appropriate for the testing sessions.

WHAT HAPPENS IF I DECIDE TO WITHDRAW?
Your participation in this research is voluntary. You may withdraw from this study at any time. You do not have to provide a reason. There will be no penalty or loss of benefits if you choose to withdraw. Your future academic status and/or relationships with your Strength and Conditioning facility or the University of Saskatchewan will not be affected

If you choose to enter the study and then decide to withdraw later, all data collected about you during your enrolment will be retained for analysis.

WILL I BE INFORMED OF THE RESULTS OF THE STUDY?
The results of the study will be provided to you after the study is complete. Each participant will be sent their own personal results document via email. The email will contain their personal data from all outcome measures along with a brief explanation of each variable. The document will also summarize initial group findings from the research and the implications for real-world application. All group findings will be presented as aggregate information, so your identity will never be disclosed.

WHAT WILL THE STUDY COST ME?
You will not be charged for any research-related procedures. You will not be paid for participating in this study. You will not receive any compensation, or financial benefits for being in this study, or as a result of data obtained from research conducted under this study.

WHAT HAPPENS IF SOMETHING GOES WRONG?

In the case of any medical emergency that may arise during testing, trained staff and emergency protocols will be in-place to ensure immediate professional response to the situation. Necessary medical treatment will be made available at no cost to you. By signing this document, you do not waive any of your legal rights.

WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?
Your confidentiality will be respected. No information that discloses your identity will be released or published without your specific consent to the disclosure. However, research records identifying you may be inspected in the presence of the Investigator or his or her designate by representatives from the University of Saskatchewan Research Ethics Board for the purpose of monitoring the research. However, no records, which identify you by name or initials, will be allowed to leave the Investigators' offices. The results of this study may be presented in a scientific meeting or published, but your identity will not be disclosed. If the researcher happens to take a video and/or photograph of you during your testing session, any identifying factors will be concealed to maintain your anonymity.

WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY?
If you have any questions or desire further information about this study before or during participation, you can contact *Dr. Scotty Butcher by email at scotty.butcher@usask.ca* or *Kelsi Kowalchuk by email at kjk646@usask.ca or by phone at 306-551-6055.*

If you have any concerns about your rights as a research participant and/or your experiences while participating in this study, contact the Chair of the University of Saskatchewan Research

Ethics Board, at 306-966-2975(out of town calls 1-888-966-2975). The Research Ethics Board is a group of individuals (scientists, physicians, ethicists, lawyers and members of the community) that provide an independent review of human research studies. This study has been reviewed and approved on ethical grounds by the University of Saskatchewan Research Ethics Board.

UNIVERSITY OF
SASKATCHEWAN

CONSENT TO PARTICIPATE

Study Title: Assessing a flywheel eccentric overload squat test in strength trainees: a feasibility study

- I have read the information in this consent form.
- I understand the purpose and procedures and the possible risks and benefits of the study.
- I was given sufficient time to think about it.
- I had the opportunity to ask questions and have received satisfactory answers.
- I understand that I am free to withdraw from this study at any time for any reason and the decision to stop taking part will not affect my future relationships.
- I give permission to the use and disclosure of my de-identified information collected for the research purposes described in this form.
- I understand that by signing this document I do not waive any of my legal rights.
- I will be given a signed copy of this consent form.
- I agree to have videos and/or photos taken of me during this study (circle one)

YES NO

- I would like to receive a copy of the research paper for this study when it is available.

YES NO

- I agree to be contacted for similar research studies in the future (circle one)

YES NO

I agree to participate in this study:

Contact email:

Printed name of participant: Signature Date

Printed name of person obtaining consent: Signature Date

Appendix B

Get Active Questionnaire (GAQ)

CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Get Active Questionnaire

CANADIAN SOCIETY FOR EXERCISE PHYSIOLOGY –
PHYSICAL ACTIVITY TRAINING FOR HEALTH (CSEP-PATH®)

Physical activity improves your physical and mental health. Even small amounts of physical activity are good, and more is better.

For almost everyone, the benefits of physical activity far outweigh any risks. For some individuals, specific advice from a Qualified Exercise Professional (QEP – has post-secondary education in exercise sciences and an advanced certification in the area – see csep.ca/certifications) or health care provider is advisable. **This questionnaire is intended for all ages – to help move you along the path to becoming more physically active.**

☐ I am completing this questionnaire for myself.
☐ I am completing this questionnaire for my child/dependent as parent/guardian.

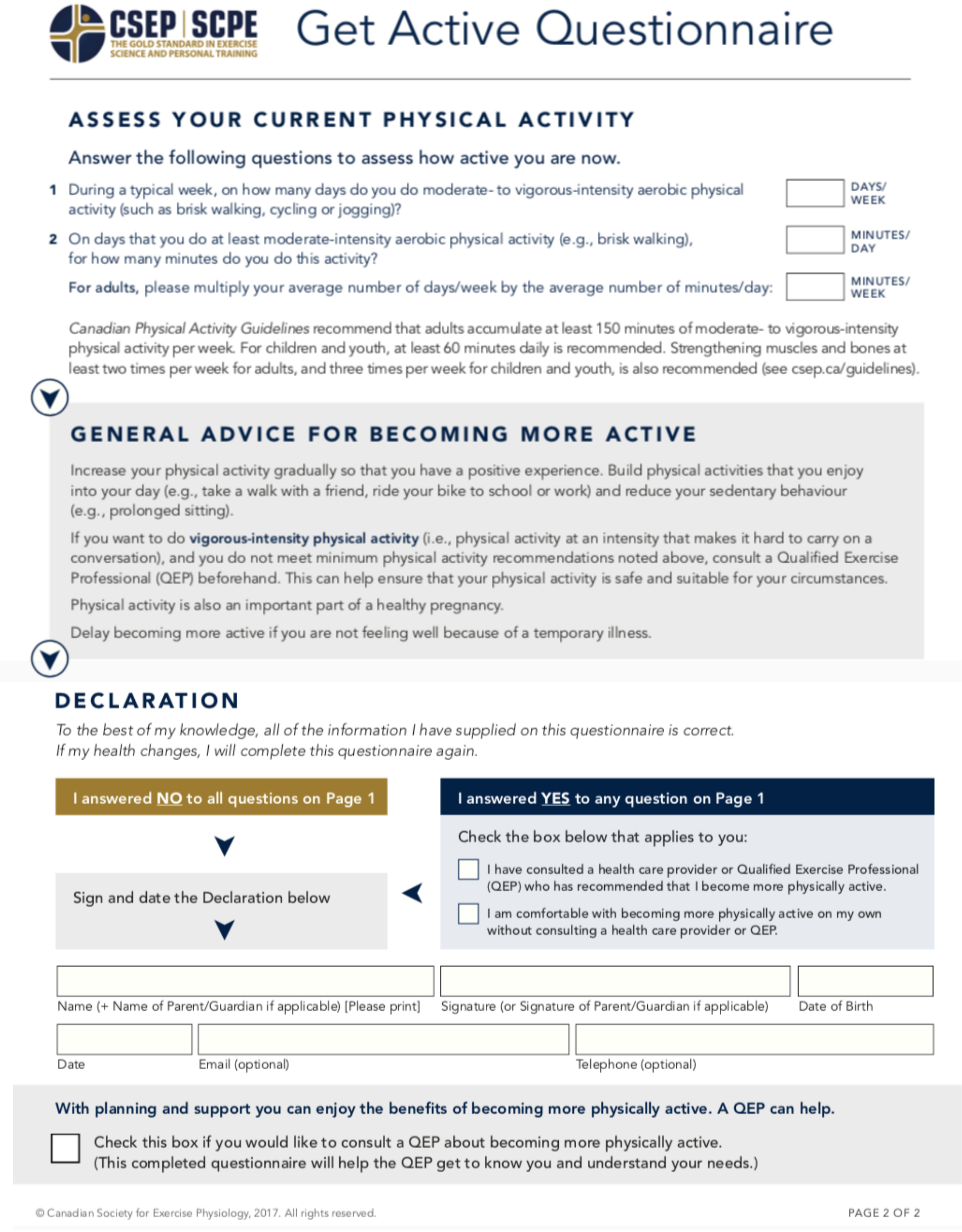
PREPARE TO BECOME MORE ACTIVE

The following questions will help to ensure that you have a safe physical activity experience. Please answer **YES** or **NO** to each question <u>before</u> you become more physically active. If you are unsure about any question, answer **YES**.

✓ YES	✓ NO	
		1 Have you experienced **<u>ANY</u>** of the following (A to F) **within the past six months**?
○	○	**A** A diagnosis of/treatment for heart disease or stroke, or pain/discomfort/pressure in your chest during activities of daily living or during physical activity?
○	○	**B** A diagnosis of/treatment for high blood pressure (BP), or a resting BP of 160/90 mmHg or higher?
○	○	**C** Dizziness or lightheadedness during physical activity?
○	○	**D** Shortness of breath at rest?
○	○	**E** Loss of consciousness/fainting for any reason?
○	○	**F** Concussion?
○	○	**2** Do you currently have pain or swelling in any part of your body (such as from an injury, acute flare-up of arthritis, or back pain) that affects your ability to be physically active?
○	○	**3** Has a health care provider told you that you should avoid or modify certain types of physical activity?
○	○	**4** Do you have any other medical or physical condition (such as diabetes, cancer, osteoporosis, asthma, spinal cord injury) that may affect your ability to be physically active?

······➤ **<u>NO</u>** to all questions: go to Page 2 – ASSESS YOUR CURRENT PHYSICAL ACTIVITY ·······➤

<u>YES</u> to any question: go to Reference Document – ADVICE ON WHAT TO DO IF YOU HAVE A YES RESPONSE ···➤➤



CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Get Active Questionnaire

ASSESS YOUR CURRENT PHYSICAL ACTIVITY

Answer the following questions to assess how active you are now.

1	During a typical week, on how many days do you do moderate- to vigorous-intensity aerobic physical activity (such as brisk walking, cycling or jogging)?	☐ DAYS/ WEEK
2	On days that you do at least moderate-intensity aerobic physical activity (e.g., brisk walking), for how many minutes do you do this activity?	☐ MINUTES/ DAY
	For adults, please multiply your average number of days/week by the average number of minutes/day:	☐ MINUTES/ WEEK

Canadian Physical Activity Guidelines recommend that adults accumulate at least 150 minutes of moderate- to vigorous-intensity physical activity per week. For children and youth, at least 60 minutes daily is recommended. Strengthening muscles and bones at least two times per week for adults, and three times per week for children and youth, is also recommended (see csep.ca/guidelines).

GENERAL ADVICE FOR BECOMING MORE ACTIVE

Increase your physical activity gradually so that you have a positive experience. Build physical activities that you enjoy into your day (e.g., take a walk with a friend, ride your bike to school or work) and reduce your sedentary behaviour (e.g., prolonged sitting).

If you want to do **vigorous-intensity physical activity** (i.e., physical activity at an intensity that makes it hard to carry on a conversation), and you do not meet minimum physical activity recommendations noted above, consult a Qualified Exercise Professional (QEP) beforehand. This can help ensure that your physical activity is safe and suitable for your circumstances.

Physical activity is also an important part of a healthy pregnancy.

Delay becoming more active if you are not feeling well because of a temporary illness.

DECLARATION

To the best of my knowledge, all of the information I have supplied on this questionnaire is correct.
If my health changes, I will complete this questionnaire again.

I answered NO to all questions on Page 1

Sign and date the Declaration below

I answered YES to any question on Page 1

Check the box below that applies to you:

☐ I have consulted a health care provider or Qualified Exercise Professional (QEP) who has recommended that I become more physically active.

☐ I am comfortable with becoming more physically active on my own without consulting a health care provider or QEP.

Name (+ Name of Parent/Guardian if applicable) [Please print]

Signature (or Signature of Parent/Guardian if applicable)

Date of Birth

Date

Email (optional)

Telephone (optional)

With planning and support you can enjoy the benefits of becoming more physically active. A QEP can help.

☐ Check this box if you would like to consult a QEP about becoming more physically active.
(This completed questionnaire will help the QEP get to know you and understand your needs.)

PAGE 2 OF 2

Appendix C

Methodology Protocols, Software and Hardwar set up

Muscle oxygenation electrode placement on the midpoint of the vastus lateralis

Step 1	With the participant standing, using the ball of the palm, a hand is rubbed along the lateral thigh to pelvis to find a notch, which is the greater trochanter of the femur.
Step 2	Mark this spot by getting participants to hold their finger in the spot indicated.
Step 3	With the participant sitting, move your hand along the knee, locating the lateral knee joint.
Step 4	Mark this spot with a permanent marker.
Step 5	Take a measuring tape and extend it from the greater trochanter, the point held by participants and down to the marked spot at the lateral knee joint.
Step 6	Take this measurement and record.
Step 7	Locate the one third distance from the lateral knee joint to the greater trochanter of the femur measurement on the tape measure and mark with a vertical line, using permanent marker.
Step 8	Place the NIRS electrode over the marked spot, over the midpoint of the vastus lateralis.
Step 9	Secure with a tensor bandage wrapped tightly around, to eliminate light from entering the electrodes.

Protocol of EMGworks Software Protocol Set-Up:

Step 1 After logging onto the EMG computer, the “EMGworks Acquisition” was opened which was located on the desk top.

Step 2 Two options appeared. The “workflow environment pro” option was selected.

Step 3 The main workflow screen appeared. Projects are stored here. For a new project, “new” was selected and an appropriate titled was entered.

Step 4 The file folder was double clicked to enter in order to create to research protocol.

Step 5 The “test configuration manager” has been opened and here a new protocol can be entered.

Step 6 The first protocol entered was for the first testing session which included the QST, MVC’s, TUG, FTSTS and the SCPT. This was designated as “First test session”.

Step 7 The “hardware” option was selected to ensure the Delsys tringo system was selected. If not, the double arrow button was selected to connect to the system.

Step 8 The “sensors” option was selected. Drag and drop was used to place sensors on the anatomical body displayed. Sensor 1 was placed on the rectus femoris, sensor 2 was placed on the vastus lateralis, and sensor 3 was placed on the vastus medialis.

Step 9 Extra sensors were removed from the protocol by right clicking and selecting the “remove” option.

Step 10 Next, the “experimental workflow” tab was selected.

Step 11 Again, the drag and drop option was used to enter the tests in the desired protocol.

Step 12 The protocol consisted of: signal preview for all three sensors used (for each muscle), the QST, the MVC recordings, two TUG tests, two FTSTS tests, and two SCPT. For all tests entered, all three sensors were indicated to record muscle activity. The run time for all tests were approximately 2 minutes which could be shortened during the testing session by hitting the “stop” button.

Step 13 Once the protocol was complete, if all parameters have been entered correctly, the option to “run” the test was highlighted at the bottom on the screen. To test the protocol, “start test” was selected and the protocol was conducted by the primary researcher.

Step 14 If a “caution” symbol was noted throughout the protocol, an error existed and the protocol was revisited by the primary researcher and corrected. Possible errors included too short of run time, missing run time or missing an electrode for the recording.

Step 15 The protocol set can be randomized by clicking and dragging the various tests entered. This was tested by the primary researcher and was then randomized based upon the protocol set forth for each participant.

Step 16 The second testing day protocol also needed to be entered into the EMGworks software. Steps 5 to 11 were repeated with the new folder being titled “Second test session”.

Step 17 The protocol consisted of: signal preview for all three sensors used (for each muscle), the QST, MVC recordings, three kBox tests for each kBox trial conduced, concentric dynamometer and the eccentric dynamometer recording. For all the tests entered, all three sensors were indicated to record muscle activity. The run time for all tests were set for 10 minutes due to the longer duration the concentric and eccentric tests took to be conducted properly. This could be shortened by during the testing session by hitting the “stop” button.

Step 18 Once the protocols for the second testing day were set, steps 13 to 15 were repeated to ensure all parameters were entered correctly.

Step 19 On the day of testing, the primary researcher opened the EMGworks software and located the desired folder and protocol as indicated.

Step 20 Once here, participant information including code, name, age, height, weight and sex could be entered and saved. The protocol was changed that day to meet the randomized protocol set before the participants arrival.

Step 21 The protocol was started by clicking “start test” and could be paused and resumed at any time during the testing session as needed.

Step 22 When the protocol tests had been completed and data was collected, the “analyze” button was selected.

Step 23 The participants data for each test was then transferred into the EMGworks acquisition for further analysis. Folder name was saved by participants assigned code. This could be opened or transferred if needed for further analysis.

Protocol of Dynamometer Set-up for Individual Settings

Step 1 Have participant sit in the dynamometer chair by stepping up on the platform and placing themselves carefully in position.

Step 2 Move the dynamometer chair to ensure the rotational axis of the participants knee was in line with the rotational axis of the dynamometer.

Step 3 Adjust the dynamometer arm length so the base of the pad is positioned and resting directly above participants lateral malleolus.

Step 4 Secure the strap and pad and ask participants to extend and relax their leg to ensure settings felt comfortable.

Step 5 Make adjustments accordingly to ensure participant is comfortable. Repeat step 4 if necessary.

Step 6 Record all adjustment values used for set-up in the following testing session.

Step 7 Secure the participant in the dynamometer through both the shoulder harness around the front of their body and the leg strap around the left quadricep.

Timing Gate Set up Protocol

Step 1 A matching pair of timing gates was found from storage, one labelled “A” and the other “B”.

Step 2 The legs of each of the gates were extended, placing the set-up timing gates apart from one another, facing each other with the kBox between.

Step 3 Height of the timing gate legs were then adjusted to an height estimated to be appropriate for squatting.

Step 4 The power button on timing gate “A” was held down until a sharp beep was heard. This indicates the timing gate is on and that the distance from “B” is appropriate.

Step 5 Timing gate “A” buzzes, indicating it is waiting to connect to timing gate “B”.

Step 6 The power button on timing gate “B” was held until “A” and “B” are connected which was indicated by the cease of buzzing.

Step 7 Timing gate alignment was adjusted to ensure a correct connection between “A” and “B”.

Step 8 Participant was then asked to step up onto the kBox.

Step 9 A ginormiter was used to determine the quarter squat stance of the participant by having a 135 degree bend in the knees.

Step 10 Participants were asked to hold this position as the timing gates were adjusted to this height. Timing gates were moved so the line between “A” and “B” would be broken at this point, which indicated participants achieved the proper stance before the eccentric pull.

Step 11 It is explained to the participant that they must hear the buzz before the eccentric pull of the kBox to help standardize their squat depth each repetition.

Step 12 Participants then practiced squatting to get a sense of the sound they would hear when the quarter squat was achieved.

Step 13 Participants were then allowed a practice session on the kBox to assist in the understanding of the protocol.

Dynamometer Protocol and ROM set-up:

Step 1 The large black button was flicked on, initiating the start-up of the HUMAC NORM dynamometer.

Step 2 The compute of the dynamometer was then powered on by holding the small circular button located at the base of the equipment.

Step 3 Once loaded, the "HUMAC 2008" option located on the desk top was right-clicked and it was chose to "run as administrator".

Step 4 The download/set-up automatically initiated and the primary researcher was prompted to "begin test" in which it was instructed to move the dynamometer arm from the "t" position to the resting position as "z".

Step 5 Once loaded, the patient "Kelsi Kowalchuk" was selected as this is the location of the desired protocol which was entered previously by the researcher.

Step 6 Once "Kelsi Kowalchuk" was highlighted, the "ok" button was selected.

Step 7 The desired test "knee extension/flexion" was selected.

Step 8 The screen now displayed the specific tests that can be selected and conducted. The desired test was selected and "ok" was clicked to move forward. Each desired test was described in the body of the thesis, as the general steps for each test is what will be discussed next.

Step 9 The researcher was prompted to select which leg is being tested, "right" was selected as well as "single test" in order to conduct each test protocol (con/ecc/iso) one at a time and not subsequently.

Step 10 A screen with information about the test protocol appeared. Information regarding the test and participants position was verified and "ok" was selected to proceed.

Step 11 To set anatomical zero, participants were asked to fully extend their leg. Once indicated, the primary researcher marked the anatomical zero on the dynamometer.

Step 12 Participants relaxed their extended leg, but the primary researcher held it in place to conduct the gravity correction. Once the "gravity correction" was selected, participant's limbs were located in place and the limb was weighed.

Step 13 Participants were asked to relax back to flexion as the researcher now set the range of motion (ROM). The ROM desired was 75 degrees and participants' legs were moved as necessary with their permission.

Step 14 Once the ROM was determined, “ok” was selected. The dynamometer then produced the mechanical stopper placements based upon the ROM set.

Step 15 The primary researcher moved the mechanical stoppers to their indicated place and locked them in at each setting by securing the top latch downwards.

Step 16 The test desired then began. Participants were then provided instruction as to what test they are conducting, why as well as a demonstration by the primary researcher as what is expected of them.

Step 17 Once the desired test was completed, data was saved on the dynamometer based upon the date and time the test was conducted. This date and time was also recorded in case reference was needed at a later date.

Step 18 Data was immediately transferred by USB to the primary researcher’s computer and input into an excel spread sheet for storage and later analysis.