A Comparative Study on the Effects of Eccentric Flywheel Overload Training and Traditional Resistance Training on Physiological/Functional Performance in Healthy Older Adults

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ABSTRACT

Introduction: Older adults experience certain deleterious effects associated with aging among which include; declines in muscle strength, muscle mass, motor unit activation, muscle power and functional performance. Two strength training methods (Traditional resistance training and Eccentric flywheel overload training) have been suggested as effective means of combating these age-related declines and are of interest to us in this study. Limited research exists however, ascertaining the superiority of either training method.

Purpose: This research sought to compare the effects of eccentric flywheel overload training and traditional resistance training on muscle strength, muscle thickness, body composition (lean/fat mass) and functional performance in healthy older adults

Methods: For inclusion, individuals had to be older adults aged 55 and above, healthy, active and untrained. Twenty-three participants were randomly assigned to one of two groups: the Eccentric Flywheel Overload Training group (EFOT) or the Traditional Resistance Training Group (TRT). Measurements included muscle strength, muscle thickness, body composition (lean and body mass) and functional performance (30s sit to stand, incremental shuttle walk test, functional reach test, and up and down stair climb power test) assessed pre/post.

Results: Both training programs resulted in increases in isometric peak torque ($p < .001$), eccentric peak torque ($p < .001$), 4 repetition maximum back squat ($p < .001$), 4 repetition maximum bench press ($p < .001$) and 4 repetition maximum deadlift ($p < .001$) over time. There were also similar increases over time in lean mass ($p < .001$), 30s sit to stand ($p < .001$) and up and down stair climb power ($p = .04$) tests. Similar decreases in fat mass ($p < .001$) were also reported in both groups. No significant differences were found over time in both groups on muscle thickness, functional reach and incremental shuttle walk.

Our study revealed there were no significant differences between groups over time.

Conclusion: The present study indicates that both EFOT and TRT are similarly effective for improving isometric, and eccentric muscle strength, 4RM squat, bench press and deadlift, body composition (lean/fat mass), and functional performance (30s sit to stand and up and down stair climb power) in healthy older adults.

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DEDICATION

I dedicate this thesis to God who made this possible. Secondly, I would like to dedicate this thesis to my family members. I am forever grateful for their continual support and words of encouragement at times when it seemed like there was no way forward.

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GLOSSARY OF TERMS AND ABBREVIATIONS

ACSM: American College of Sports Medicine (ACSM, 2009)

Atrophy: reduction in muscle size due to disuse or inactivity (Bonaldo & Sandri, 2013)

ASIS: Anterior Superior Iliac Spine (Martin et al. 2017).

Concentric Contraction: This muscle action assesses the amount of force an individual generates when the muscle shortens (Roig et al. 2008)

CSEP: Canadian Society for Exercise Physiologists (CSEP, 2017)

Eccentric Contraction: This muscle action assesses the amount of force an individual generates when the muscle lengthens (Roig et al. 2008)

EFOT: Eccentric Flywheel Overload Training (Maroto-Izquerdo et al. 2017; Vicens-Bordas et al. 2018; Suchomel et al. 2019)

EMG: Electromyograph (Aagaard et al. 2000; Bawa, 2002)

FRT: Functional reach test (Duncan et al. 1990)

Hypertrophy: increase in muscle/bulk due to training (Boonyarom & Inui, 2006)

Isometric Contraction: contraction where the muscle keeps the same length despite increasing tension. There is also no movement in the joint during this contraction (Roig et al. 2010: Padulo et al. 2013).

MT: Muscle Thickness (Ticinesi et al 2018)

Omnibus ANOVA: Tests the overall significance of a Factorial ANOVA with an F value, giving a main effect for group, time and an interaction effect (Chen et al. 2018)

Physical Function: It has the following synonyms; functional performance, functional mobility, physical performance, functional capacity, functional capability- Physical performance is commonly understood as the observable ability to perform tasks, e.g. chair rise, climb stairs and walk (Sakamoto & Ohashi, 2017)

Power Training: In this review, power training would be used in different contexts like high velocity resistance training (Porter, 2006)

RFE: Residual Force Enhancement (Minozzo & Barbosa de Lira, 2013)

RM: Repetition maximum (Seo et al. 2012)

Strength Training: In this review, strength training would be used in different contexts like traditional resistance training, weight training, low velocity resistance training or resistance training (Roig et al. 2008)

TRT: Traditional Resistance Training (Kibele & Behm, 2009)

UDSCPT: Up and down stair climb power test (Raj et al. 2012)

VL: Vastus Lateralis (Ticinesi et al. 2018)

30s STS: 30-second sit to stand (Millor et al. 2013)

1.0 CHAPTER ONE: INTRODUCTION

It is well known that muscle strength plays a significant role in maintaining functional capability/mobility, and disability prevention in older adults. Loss of muscle strength and muscle mass are associated with reduced functional performance (Evans & Lexell, 1995; Pillips et al. 2005; Kalyani et al. 2014), increased disease incidence, and disability (Wolfe, 2006; Brady & Straight, 2014). Eighteen percent of the population above age 65 depends on others to carry out certain daily tasks (King et al. 2002) and 30 percent of individuals aged 60 and above are likely to fall within a 12-month period (Voukelatos et al. 2007). Without adequate training, muscle strength typically decreases by 10-20% per decade in adults over the age of 40 (Frontera et a. 1991; 2000).

Resistance training is a very important training method to be considered in maintaining muscle mass, strength, and functional performance (Tiggemann et al. 2016). Although, resistance training often involves movements/exercises done isometrically, concentrically or eccentrically, it is possible for training regimens or workout routines to specifically focus on a certain type of muscle contraction; isometric, concentric and eccentric (Wernbom et al. 2007). Isometric contractions involve muscles activating but neither shortening nor lengthening. Concentric actions involve muscles shortening; a typical example would be the upward motion of a biceps curl. Eccentric contractions involve muscles lengthening under tension; a typical example would be the downward portion of a biceps curl (Roig et al. 2010; Padulo et al. 2013) Eccentric contractions cause more damage to the muscles than isometric and concentric contractions (Westing et al. 1991). These concepts will be further discussed in the following chapter.

Traditional resistance training commonly involves free weights and weight stack machines (Norrbrandet al. 2010). A systematic review carried out by Latham et al. (2004) revealed that traditional progressive resistance training is effective for improving muscle strength and some aspects of functional limitation like gait speed in older adults. Traditional resistance training involves lowering and lifting a constant load using weight machines available (Reeves et al. 2009). This type of training seeks to provide a sufficient mechanical stimulus necessary to overload the skeletal muscle. While this goal is most likely achieved during the concentric phase (lifting) of the exercise, there is a possibility that the eccentric phase (lowering) will always be underloaded during the contraction (Katz et al. 1939; Reeves et al. 2009). This would mean that traditional resistance exercises might be more favorable to the concentric portion of an exercise. Due to the limitation associated with traditional resistance training (Norrbrand et al. 2010; 2011), researchers have sought to identify a means of training that takes into consideration both the concentric and eccentric portions during an exercise without underloading either of the two (Roig et al. 2008).

Despite the limitations that accompany aging, existing research suggests that eccentric strength in older adults is maintained (Roig et al. 2010). This maintenance of eccentric strength has made eccentric training a promising opportunity for exercise rehabilitation and morbidity/disease prevention in older adults. The interest in eccentric strength stems from previous research indicating the lower energy cost per unit of work (Curtin et al. 1975) associated with eccentric training, and also the potential to generate higher levels of force (Hollander et al. 2007; Hortogbayi et al. 1990) when compared to concentric training at the same workload. This is an advantage to older adults who are already limited in strength and mobility due to aging. It will also be useful for clinical populations with lower aerobic capacity and increased risks of cardiac issues. Furthermore, previous research carried out involving healthy older adults and eccentric training mainly focused on single muscle exercises (Greenwood et al. 2007; Onambele et al. 2008; Norrbrand et al. 2008;2010). A very common one that has been used to assess muscle strength is the knee extension exercise (Greenwood et al. 2007; Onambele et al. 2008; Norrbrand et al. 2008;2010).

Based on our review of existing literature, we were able to identify that there is minimal research involving eccentric training using multiple muscle groups (compound), like squats in healthy older adults (Maroto-Izquerdo et al. 2017; Vicens-Bordas et al 2018). Compound exercises like squats positively influence the balance and functionality of older adults (Sanudo et al. 2019). A recent study, undertaken by Sanudo et al. (2019) involved 36 individuals aged 60 and above, split into two groups; squat flywheel eccentric exercise group or control group (where individuals performed regular daily activities; leisure or employment). The flywheel group underwent training two or three times a week for a period of 6 weeks. At the end of the intervention, the flywheel group showed improvements in balance and mobility when compared to the control group, which were assessed by measuring center of pressure and timed up and go respectively. Compound exercises like squats could possibly be more efficient in improving muscle strength than isolation exercises (Paoli et al. 2017; Gonclave et al. 2019);

however, this has been debated by some studies (Gentil et al. 2013; Franca et al. 2015). The American College of Sports Medicine’s (ACSM) resources for a Personal Trainer (2014) indicate that compound exercises (exercises that involve more than one muscle group) are able to activate several different muscle groups at the same time, making these kinds of exercises ideal not just for older adults, but for individuals trying to see improvements within a short period of time (Gonclave et al. 2019).

A more modernized approach to resistance training would be the flywheel inertial technology, which over the years has begun to gain popularity and has led to the production of readily available commercial flywheel devices. The YoYo flywheel technology is the most studied laboratory device and was developed by Per Tesch (Onambele et al. 2008; Tesch et al. 2017) a well-known professor of physiology. However, for our study we will be using another commercially available inertial device called the kinetic box-Kbox (Exxentric AB, Broma, Sweden). Unlike traditional resistance training, flywheel resistance training uses inertial resistance that is generated from the uncoiling of the flywheel’s strap brought about by a concentric muscle action, after which the recoiling results in an eccentric muscle action. In simple terms, resistance is generated by the rotation of the wheel around its axis as an individual goes up and down (squat) in concentric and eccentric actions. The amount of force or effort an individual puts in during the concentric phase determines the amount of force generated in the eccentric phase. Currently, just 3 studies exist involving healthy older adults and flywheel training (Onambele et al. 2009; Bruseghini et al. 2015; Sanudo et al. 2019). These studies indicate that flywheel training can effectively improve muscle power, balance (thereby increase functional mobility and reducing risks of falls), and quadriceps muscle strength. A definite advantage of the flywheel technology over traditional resistance training is its ability to overload the eccentric portion of an exercise, without any assistance by a partner or trainer (Suchomel et al. 2019). This is not to say however, that traditional resistance training does not allow for eccentric overload.

The limitations associated with traditional resistance training in terms of applying an eccentric overload has influenced our interest in eccentric flywheel overload training. In addition, research comparing eccentric flywheel overload training and traditional resistance training is limited and we would like to shed more light on these training methods in healthy older adults (Maroto-Izquerdo et al. 2017; Sanchez et al. 2017; Petre et al. 2018; Vicens-Bordas et al. 2018).

1.1 Objective

The aim of the study is to identify the influence of Eccentric Flywheel Overload Training compared with Traditional Resistance Training on muscle strength, muscle thickness, body composition, and functional performance of older adults.

1.2 Research Questions

1. Can Eccentric Flywheel Overload Training result in greater increases in isokinetic knee extension strength, squat strength, lean mass; than traditional resistance training within a whole-body strength program in healthy older adults?

2. Can Eccentric Flywheel Overload Training result in greater increases in functional performance than traditional resistance training within a whole-body strength program in healthy older adults?

1.3 Hypotheses

1. Within a whole-body strength program, eccentric flywheel overload training will result in greater increases in isokinetic knee extension strength, squat strength, bench press strength, deadlift strength, and lean mass than traditional resistance training in healthy older adults

2. Within a whole-body strength program, eccentric flywheel overload training will result in greater increases in functional performance (sit to stand, incremental shuttle walk, functional reach and stair climb power) than traditional resistance training in healthy older adults

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 Background

For decades muscle strength and power training have been used to combat the deleterious effects of aging. Individuals above the age of 40 years lose about 10-20% percent of their muscle strength per decade (Frontera et al. 1991; 2000). Reductions in strength and power have been associated with functional dependence/physical limitations (such as difficulty walking or standing for extended periods of time, stooping, bending, kneeling, climbing stairs), disabilities (activity limitations, impairments and participation restrictions), and increased risk of falls amongst other negative effects (Wolfe, 2006; Philips, 2007; Brady & Straight, 2014). These negative health effects may result in greater medical attention which in turn increases the costs of health care (Brady & Straight, 2014). Research done on the Canadian population by Katzmarzyk et al. (2000) revealed that about $2.1 billion or 2.5% of the total direct health care costs were attributable to physical inactivity in 1999. They also reported that a 10% reduction in the prevalence of physical inactivity has the likelihood of reducing direct health costs by $150 million a year (Katzmarzyk et al. 2000).

2.2 Understanding Muscle Contraction

The process of building strength, power and muscle mass in an individual requires certain muscle actions. These muscle actions (shortening and lengthening) are responsible for basic human movement (Dias et al. 2015).

Broadly, muscle contractions (Figure 2.1) can be classified under 3 categories; isometric, concentric, and eccentric contractions (Roig et al. 2010; Padulo et al. 2013*)*.

a. Isometric contractions usually involve static contraction of a muscle. During the process of the muscle action there is no specific change or movement in the angle of the joint (Roig et al. 2010: Padulo et al. 2013*)*.
b. Concentric contractions involve shortening of a muscle. A good example would be extending the knee joint (contracting the quadriceps) (Roig et al. 2010: Padulo et al. 2013)
c. Eccentric contractions involve lengthening of a muscle. A good example would be flexion of the knee joint (active lengthening under tension) (Roig et al. 2010: Padulo et al. 2013).

Note: Concentric and eccentric actions can be isotonic (muscles change length, but tension is maintained) or isokinetic (involving movements that require constant speed and changes in muscle length). Isokinetic concentric and eccentric actions will be used for this study.

Most muscle actions involve isometric, eccentric and concentric actions and these are evident in most strength/power training programs undertaken (Cormie et al. 2011; McGuigan et al. 2012; Beattie et al. 2014). Beyond that, we make use of these actions everyday as human beings (Muthalib et al. 2010). The focus of this study will be mostly on eccentric strength and training; some of the advantages of this method of training will be highlighted below.

Isotonic/Isokinetic Contraction		Isometric Contraction
Concentric	Eccentric	
		
Concentric action in the quadriceps during the upward phase of the squat	Eccentric action in the quadriceps during the downward phase of the squat	Isometric contraction occurs in the quadriceps when the muscle hold the weight still during a squat
Quadriceps shorten under tension	Quadriceps lengthen under tension	Unlike the concentric and eccentric contraction, tension is generated by the quadriceps, but the muscles don't shorten or lengthen (stays the same)

Figure 2.1: Picture showing types of muscle contractions

2.3 Physiological Changes with Aging

2.3.1 Muscle strength

Muscle strength can be defined as the maximum effort an individual can generate in a single repetition (Brady & Straight, 2014). According to Manini & Clark (2011), dynapenia can be defined as an age-related loss of muscle strength and power. For example, dynapenia could occur when there is an impairment in neural (central) activation which could be a result of a reduction in descending excitatory drive from supraspinal centers and/or suboptimal motor unit recruitment and firing frequency (Manini & Clark, 2011). This suggests that loss of muscle strength in older adults could be attributable to neural and muscular factors. In addition, dynapenia could occur when there is a reduction in the intrinsic force-generating capacity of muscle, changes in actomyosin structure/function and infiltration of adipocytes into muscle fibres (Manini & Clark, 2011). When compared to younger individuals, older adults (aged 55 and above) have lower strength levels (Bouchard et al. 2011; Marcell et al. 2014). This is expected as we have already established that an increase in age is associated with a decrease or reduction in strength. A longitudinal study comprised of healthy older adults (aged 50-80 years) reported that there was a loss in quadriceps muscle strength annually in both men (3.6%) and women (2.8%). Interesting to note was the even greater reduction in muscle strength in endurance trained older adults and this was over a 5-year period. Knee flexion strength underwent a decline of between 3-4% while knee extension strength underwent a decline of 4-5% with no significant differences between men and women (Marcell et al. 2014).

2.3.2 Muscle mass

Muscle mass decreases with age, and this is referred to as sarcopenia. Sarcopenia is due to both the loss of muscle fibers and fiber atrophy (Doherty 2003; Lexell 1995) accompanied by increased infiltration of non-contractile components such as connective tissue and fat (Overend et al. 1993). The loss of muscle strength is attributed to the structural changes alongside impaired neural function (Skelton et al. 1994).

The mechanisms responsible for muscle atrophy and loss of neural innervation are not fully understood; however, the following could be major contributing factors to the loss of muscle mass: reduced physical activity, decline in anabolic hormone levels (dehydroepiandrosterone, testosterone, growth hormone) concomitant with a chronic low-grade inflammation (increased tumor necrosis factor and cortisol serum levels) (Doherty 2003; Vandervoort 2002).

Individuals over the age of 50 undergo 1-2% decreases in muscle mass per year (Quittan, 2016). A reduction in muscle mass has been shown to have associations with functional impairments and possibly physical disability (Janssen et al. 2002). These findings were identified in a study conducted by Janssen et al (2002), in the bid to establish the prevalence of sarcopenia in older adults and to assess whether sarcopenia is associated with functional impairment and physical disability in older persons. Another study conducted by Visser et al. (2002) revealed that smaller midthigh muscle area and greater fat infiltration in the muscle were associated with poorer lower extremity performance in well-functioning men and women.

Research shows however that a higher amount in muscle mass in the body than fat mass could possibly reduce the risk of prediabetes in adults. The ideology behind this is based off of a study conducted by the National Health and Nutrition Examination Survey III (Mann, 2011) on 13,644 adults. They found that for every 10% increase in skeletal muscle index (ratio of muscle mass to total body weight), there was a reduction of 11% in insulin resistance and a reduction of 12% in prediabetes. In simple terms, from the above it can be suggested that a higher amount of muscle mass could possibly result in a higher usage of insulin which can prevent or slow down the risk for diabetes.

Summarily, muscle strength and muscle mass are both important factors that contribute to the functional performance or capability of individuals. Existing research confirms that both factors (muscle strength and muscle mass) have a positive correlation, indicating that when there is an increase in one the other increases and vice versa (Harris, 1997).

2.3.3 Muscle Power

Muscle power is often defined as work (force × distance) divided by time, while strength is the ability to produce torque (force) (Roig et al. 2010). In simple terms, muscle power could be regarded as strength in motion and is characterized by producing high torques within the fastest time possible (Weir & Cramer, 2006). Muscle power is more relevant than muscle strength when performing daily tasks or activities (Bassey & Short 1990; Bassey et al. 1992; Foldvari et al. 2000) and is inversely associated with mortality (Metter et al. 2004). There is a greater decrease in power (3-4% per year greater than strength) than strength (Metter et al. 1997) in older adults. This is attributed to muscle atrophy, but since power also involves rapidity of movement, muscle quality in terms of slower contractile properties is another factor (Vandervoort & McComas 1986). Type II muscle fibres have higher power-generating capacities than type I fibres and undergo greater atrophy and reduction in number with aging (Lexell et al. 1988).

2.3.4 Body composition

Body composition is a secondary component in this review; however, it is also affected by aging and this affects functional mobility. In older adults there is an increase in overall adiposity and this has been identified as a leading cause of disability (Chen & Guo, 2008; Villareal et al. 2005). Some individuals experience increases in muscle lipid content which is an independent risk factor for mobility limitations (Visser et al. 2005; Delmonico et al. 2009; Buford et al. 2012). For older women, body composition is the strongest independent predictor of physical function, while for men it is the cross-sectional area of the thigh muscle (Visser et al. 2002). Older women gain higher adiposity as they age when compared to men their age and this adiposity negatively affects their ability to function optimally (Riebe et al. 2009).

2.4 Combating Strength Loss Associated with Aging

2.4.1 Physical Activity in Older Adults

Physical Activity (PA), according to the Centers for Disease Control and Prevention can be defined as any bodily movement produced by skeletal muscle contractions that result in energy expenditure above an individual's basal level. In contrast, exercise is defined as planned, structured, or repetitive PA performed to either maintain or improve one or more components of physical fitness (Centers for Disease Control and Prevention, 2011). Aging is associated with reductions or declines in physical activity (Schoenborn et al. 2010), total volume of physical activity (Dipietro et al. 1993; Westerterp et al. 2000), intensity of physical activity and increases in sedentary time in both men and women, with women more affected than men (Westerterp et al. 2000; Rafferty et al. 2002; Schoenborn et al. 2004). Individuals between the ages of 60-69 years are more active in all domains including leisure time activity, work-related and housework, than individuals between the ages of 70-79 years (Milanovic et al. 2013). The physical activity recommendations for older adults include both resistance and aerobic training (Canadian Society for Exercise Physiologists; CSEP guidelines, 2011); however, many older adults barely achieve the minimum number of hours required for physical activity according to guidelines. Only 51.1% and 21.9% of older adults meet the aerobic and resistance training guidelines respectively (Centers for Disease Control and Prevention, 2011). Conflicting data

exist as to what the physical activity trends in older adults are and whether they are getting the sufficient physical activity they need to perform everyday tasks (Sun et al. 2013).
In summary, there are some indications that regular engagement in physical activity could help reverse some of the negative effects associated with aging (Brady & Straight, 2014). Beyond physical activity, targeted training programs could combat an increase in adiposity related to aging, loss of muscle mass, strength and power.

Despite the fact that we have established the importance of muscle strength, there seems to be some controversy as to which form of strength training would yield better results in terms of improving functional performance (Raj et al. 2012). This review will highlight some of the benefits associated with resistance training methods; EFOT or TRT, and examine some of the core concepts associated with improving strength for overall health and functional performance, most especially in older adults.

2.4.2 Strength Training (Low Velocity Resistance Training) in Older Adults

Improving muscle strength in older adults is very important and Newman et al. (2003) confirmed that there is a more robust relationship between muscle strength and function than between muscle mass and physical function (Brady and Straight, 2014). There is an increase in muscle strength in older adults after engaging in resistance training programs (Onambele et al. 2008; Dias et al. 2015). Resistance training improves strength which in turn improves functional performance and reduces the risk of falls (Gonzalo et al. 2014). Strength training is characterized by executing voluntary muscular contractions in a systematic way against external loads (American College of Sports Medicine; ACSM, 2009). Usually this would involve compound movements (multiple muscle groups) or isolation movements (focusing on a single muscle) (Wernbom et al. 2007). Training with isolated movements however takes longer to yield benefits required in older adults, as they primarily involve single muscles. A good example of when to use isolation exercises would be during rehabilitation or body building.

According to ACSM, (2013) recommendations are that individuals should engage in strength training programs for musculoskeletal fitness no fewer than 2 non-consecutive (for example, Mondays and Wednesdays or Tuesdays and Thursdays) days in a week. Other studies revealed that engaging in strength training 1-3 times a week is also effective for improving strength, body composition and functional performance in older adults (Frontera et al. 1988; Taaffe et al. 1999).

2.5 Eccentric Training and Benefits to Older Adults

2.5.1 Preservation of Eccentric Strength

Older adults are able to preserve their eccentric strength and this has been attributed to increased passive stiffness that comes with aging (Vandervoort et al. 1990; Poulin et al. 1992; Hortobagyi et al. 1995; Lindle et al. 1997; Porter et al. 1997; Lynch et al. 1999; Pousson et al. 2001; Ochala et al. 2006; Klass et al. 2007; Roig et al. 2010). According to Roig et al. (2010), the mechanisms that are responsible for this preservation of eccentric strength could be mechanical or cellular and involve passive and active elements responsible for regulating muscle stiffness. The increase in passive stiffness and accumulation of non-contractile proteins, accompanying the aging process in the muscle-tendon unit might offer a higher mechanical advantage when eccentric contractions are performed (Roig et al. 2010). Coupled with that, the increase in instantaneous stiffness and preservation of muscle tension of old muscle fibers during stretching increase active stiffness. From the above, we can deduce that there might be some advantages for older adults using eccentric contractions, especially in terms of rehabilitation and functional performance.

2.5.2 Eccentric Training and the Nervous System

According to Hedayatpour & Falla, (2015) neural adaptations to training could be defined as changes within the nervous system that allow a trainee to fully activate prime movers in specific movements and to better coordinate the activation of all relevant muscles, thereby affecting a greater net force in the intended direction of movement (Sale, 1988). Neural adaptations can occur at different levels with training; some of which are: motor cortex, spinal cord, the neuromuscular junction and excitation-contraction pathways on the distal end of the neuromuscular junction (Fang et al. 2001; Hedayatpour et al. 2014; Hedayatpour et al. 2014).

Cortical activity improves during exercise and more interestingly might differ depending on the type of exercise being engaged in (Dasilva et al. 2011; Flanagan et al. 2012; Singh et al. 2014). Eccentric exercises have been known to cause higher increases in cortical activity when compared to concentric and isometric contractions (Patten et al. 2001; Brummer at al. 2011).

This is achieved by presynaptic input gating during an eccentric (lengthening) contraction, to help reduce muscle damage and unwanted stretch reflex (Romano & Schieppati, 1987).

In addition, resistance training especially using eccentric exercises (Dartnall et al. 2009) affect motor unit firing rates, leading to an increase in the force generating capacity of a muscle (Farthing & Chilibeck, 2003). Herzog et al. (2008) were of the opinion that the increase in the force generating capacity of a muscle during eccentric contraction might be due to a decrease in the detachments of cross-bridges (i.e. an increase in the number of attached cross-bridges). They also indicated that there is a possibility of titin contributing to the additional force production observed during eccentric contractions due to an increase in "passive force enhancement. These changes can be observed in the reduction of an electromyograph (EMG) amplitude during eccentric versus concentric contractions and similarly, reductions in H reflex responses (Aagaard et al. 2000; Bawa, 2002).

2.5.3 Eccentric Training and Muscle Strength, Hypertrophy and Power

Changes in eccentric strength could be achieved by an increase in the agonist voluntary activation (Aagaard et al. 2000; Vangsgaard et al. 2014) and a decrease in the antagonist co-activation (Pensini et al. 2002). Large improvements in eccentric strength, and the observation that eccentric training increases eccentric strength to a greater degree than concentric training could be as a result of the inability of particularly untrained individuals to fully activate muscles during eccentric contractions (Beltman et al. 2004). In support of an improved neural drive, Vangsgaard et al. (2014) found that 5 weeks of eccentric training of the trapezius muscle increased muscle excitability (i.e. inferred from maximal evoked H-reflex) in concert with a 26 % increase in maximal voluntary contraction. Improvements in agonist voluntary activation during eccentric contractions may result from a disinhibition of presynaptic Golgi Ib and joint afferents known to inhibit excitatory muscle spindle Ia afferents (Aagaard, 2003). The removal of neural inhibition and the increase in the maximal amount of force produced by a muscle, alongside the rate of force development observed after eccentric resistance training could be as a result of downregulating inhibitory pathways, with likelihood of it being central descending pathways (Kaminski et al. 1998).

Skeletal muscle hypertrophy occurs as a result of chronic summation of periods of positive net protein balance after engaging in resistance training (Phillips, 2014). The synergistic stimulatory effect of resistive exercise combined with feeding on muscle protein synthesis accounts for the rise in a positive net protein balance (Biolo et al. 1997; Borsheim et al. 2002; Tipton et al. 2003). The increase in protein synthesis is channeled toward reformation and addition of cellular protein structures, myofibrillar proteins, and plays a critical role in the process of skeletal muscle hypertrophy. Most forms of resistive exercise also cause a disruption of the protein ultrastructure, commonly observed as Z-line streaming and myofibrillar disorder, that is greater with lengthening vs. shortening contractions (Gibala et al. 2000, Gibala et al. 1995).

After repetitively engaging in resistance exercises (exposure to lengthening contractions which could also be termed eccentric contractions), a combination of factors brings about a reduction in damage: the so-called "repeated-bout" effect. In terms of muscle hypertrophy, several studies have revealed that resistive muscle training using isotonic (Hather et al. 1991; Hortobagyi et al. 2001) and isokinetic (Farthing & Chilibeck, 2003; Higbie et al. 1996, Hortobagyi et al. 1996; Hortobagyi et al. 1996; Seger et al. 1998) training protocols in the absence of lengthening contractions results in less hypertrophy, and smaller strength gains, when compared to combinations of shortening and lengthening contractions. However, greater hypertrophy with isokinetic lengthening-only training programs is not always observed (Colliander et al. 1990; Jones et al. 1987, Mayhew et al. 1995). Lengthening contractions (eccentric actions) at higher velocities increase muscular strength to a greater extent than slow contractions (Farthing & Chilibeck, 2003; Paddon-Jones et al. 2001). There is a likelihood that eccentric contractions at high velocity lie on the high end of the force-velocity curve and this might be responsible for the production of higher force, resulting in greater strength increases.

2.5.4 Physiological Adaptations to Eccentric Training

Eccentric training exposes the skeletal muscles to a combination of stretch and overload which causes subcellular damage to the structural and contractile components of the skeletal muscle. The damage experienced at the subcellular level activates master signaling pathways for gene expression and muscle hypertrophy (Coffey & Hawley, 2007; Hedayatpout et al. 2008). There is an increase in the number of sarcomeres in the absence of fiber necrosis following exercise induced muscle tension (Butterfield & Herzog, 2006). Mechanical information received by the skeletal muscles convert the stimulus into biochemical events which are responsible for the regulation of the rate at which protein synthesis occurs. Eccentric training induces a more rapid addition of sarcomeres in series and in parallel as seen in muscle cross sectional area and pennation angle when compared to concentric training (Narici et al. 1989). Eccentric training results in a greater increase in fibre length in muscle when compared to concentric training (Lynn & Morgan 1994).

2.5.5 Eccentric Overload

In simple terms the eccentric portion of an exercise can be overloaded when a higher load than that of the concentric phase is achieved (Berg & Tesch, 1994; Tesch, 2017). Dias et al. (2015) highlighted 3 methods of achieving an overload in an older population; a) concentric assist phase- this is where the researcher or trainer helps the individual during the concentric phase of the lift and withdraws his/her support during the eccentric part (Valour et al. 2004; Reeves et al. 2009) b) bilateral/unilateral approach- using the leg press exercise as an example, the individual would use both legs to push the weight during the concentric phase and withdraw one leg during the eccentric phase (Raj et al. 2012) c) cycle ergometers that are specially rigged to induce eccentric contractions (Lastayo et al. 2003; Mueller et al. 2011; Purtsi et al. 2012) d) inertial flywheel devices (Onambele et al. 2008).

2.6 Traditional Approaches to Increasing Strength and Functional Performance in Older Adults

Traditional resistance training involves lifting and lowering a constant external load using commercially available machines or free-weights. The essential aim of this method of training is to provide a high mechanical stimulus that is able to 'overload' the skeletal muscle through increasing load or volume of training. Whilst this is most probably true for the exercised muscles during the concentric (lifting) phase of contraction, the same muscle will always be under-loaded during the eccentric (lowering) phase of contraction. This is because skeletal muscles are capable of developing much higher forces when they contract eccentrically than when they contract concentrically, in accordance with the force-velocity relation (e.g. Katz, 1939). One fundamental requirement of the force-velocity relation is that each value of force and velocity on this curve should belong to the same level of activation; thus, a family of force-velocity curves is obtained for different levels of activation (Bigland & Lippold, 1954; Chow & Darling, 1999; Camilleri & Hull, 2005). It follows that, if the same absolute load of the concentric phase is lowered in the eccentric phase, motor units must be de-recruited in the eccentric phase and, as a consequence, one falls onto a different force-velocity curve of lower activation level. A number of studies have reported considerable concentric strength gains in the lower limb after traditional resistance training in older adults (Macaluso & De Vito, 2004; Narici et al. 2005; Reeves et al. 2006b); however, there is a paucity of data relating to the changes in eccentric strength in response to traditional resistance training. Hortobágyi et al. (2001b) found greater gains in concentric (37%) than eccentric knee extensor strength (22%) following 10 weeks of high-intensity traditional resistance training in older adults.

The barbell squat (an example of traditional resistance training) is the most commonly used free weight exercise engaged in by athletes to enhance performance emphasizing horizontal or vertical strength, power, and speed (Chandler et al. 1989, Escamilia et al. 1998). While the closed kinetic-chain squat exercise involves multiple muscle groups (Escamilia et al. 2001, McCaw et al. 1999), movement about the knee joint is mainly brought about by the quadriceps (Escamilia et al. 1998; Ploutz-Snyder et al. 1995; Wretenberg et al. 1996). A particular disadvantage of the traditional barbell squat is that maximal effort is required only in the very last repetition of a set, ultimately leading to the inability to lift the weight (van den Tillaar et al., 2014; Kompf & Arandjelović, 2016). Hence, muscle activation and motor unit recruitment must not be complete in the vast majority of repetitions typically executed in an exercise bout (van den Tillaar et al., 2014; Kompf & Arandjelović, 2016).

In contrast, flywheel resistance exercise allows for accommodated maximal or near maximal actions from the very first repetition of a set (Berg et al. 1994, Tous-Fajardo et al. 2006). Collectively, it appears that the "semi-supine" squat employing flywheel (FS), as described elsewhere (Berg et al. 1998), would require greater usage of the muscle than the barbell squat.

2.7 Modern Approach to Increasing Strength and Functional Performance in Older Adults

Flywheel Technology and Existing Research

Inertial devices have recently gained popularity for being able to achieve eccentric overloads without an external weight change (Berg & Tesch, 1994). However, despite the common utilization of such devices, there has not been very much research conducted to study its specific effects (Maroto-Izquerdo et al. 2017; VIcens-Bordas et al. 2018). Flywheel resistance training (RT) was originally designed to maintain muscle health of astronauts during spaceflight (Berg and Tesch, 1994). This innovation came to being as a result of the observed rapid decline in the muscle mass and functionality of individuals that travel to outer space. A unique feature of this resistance training equipment is its possession of iso-inertial technology rather than the free weights used in barbell squats, which are gravity dependent. This technology allows for maximal muscle actions in both concentric and eccentric phases, with brief episodes of eccentric over-load, i.e. longer periods of contraction (Norrbrand et. al. 2008).

On a flywheel device, the concentric action against the lever arm pulls the strap and imparts spin to the flywheel against its inertia. The device is adjusted such that, at the end of the concentric action, the strap is completely unwound, and the flywheel starts to recoil the strap by virtue of its rotary inertia, thus reversing the direction of the movement. In the eccentric action the trainee resists to the recoil until the flywheel has come to a stop. Using a flywheel device, the energy generated in the concentric action is converted into kinetic energy, which is accumulated in the flywheel and removed in the subsequent eccentric action (Norrbrand et al. 2008). Previous studies have shown that the peak force generated/produced whilst the muscle is contracting eccentrically may be about 15-30% greater than such actions in the concentric phase. This observation may be due to the energy storage characteristics of the inertial system, and specific instructions to the trainee (Fernandez-Gonzalo et. al 2014). Flywheel resistance exercise produces greater muscle hypertrophy and peripheral neural adaptations than weight-loaded resistance training in healthy subjects (Norrbrand et. al. 2008, Norrbrand et. al 2010).
Given the greater mechanical efficiency of eccentric actions during traditional weight training, no eccentric action within a set will call for maximal activation. Additionally, and due to changes in biomechanical levers and muscle length, the ability to overcome the gravitational force of a weight is dictated by the "sticking point" occurring during the concentric action. As a result, standard resistance exercise, employing a constant weight, calls for maximal activation only at the "sticking point" of the very last concentric repetition resulting in failure to lift a weight (Norrbrand et al. 2010).

The inertia of spinning Flywheel(s) offers unrestrained resistance throughout the entire concentric action and allows for brief episodes of eccentric forces exceeding the concentric forces, i.e., "eccentric overload" (Norrbrand et al. 2008; Tesch et al. 2004). This is in opposition to the already addressed disadvantage of the traditional resistance weight. Thus, this exercise modality should cause maximal muscle activation in the concentric, and part of the eccentric action, through each repetition of a set. Therefore, Flywheel resistance training might induce greater EMG amplitude overall than exercises that require gravity-dependent weights (Traditional Resistance Training).

Extensive research has been carried out to quantify and better understand the usefulness of the flywheel technology in increasing strength, muscle mass, power and even functional performance in youths, middle-aged adults and older adults that have or previously had health issues (Fernandez-Gonzalo et al. 2014;2016; Maroto-Izquierdo et al. 2017; Vicens-Bordas et al. 2018). However, not much research involving healthy older adults and the flywheel technology has been done. Currently, there are only 3 studies that have been carried out involving flywheel technology and healthy older adults (Onambele et al. 2009; Bruseghini et al. 2015; Sanudo et al. 2019). The first study (Onambele et al. 2009) split older adults into either a flywheel resistance group or traditional resistance group, with 12 individuals per group. The intervention was 12 weeks, involving knee extension exercises of 8-12 repetitions which were progressively increased every session (1 to 4 sets/session). At the end of the intervention, the flywheel group when compared to the traditional resistance group, showed increases in both peak knee extension power and tendon stiffness (136%) of the gastrocnemius muscle (calf) (Onambele et al. 2009; Kowalchuk & Butcher, 2019). There were also improvements in overall body balance associated with the increases in gastrocnemius muscle tendon stiffness (Onambele et al. 2009).

The second study conducted by Bruseghini et al. (2015) involved a comparison between flywheel leg press training and aerobic interval training. For the first 8 weeks, 12 participants (healthy older adults) engaged in an interval training program using a cycle ergometer. This was followed by a washout period of 4 months, after which they engaged in another 8 weeks of flywheel leg press training, exercising 3 times a week (4 sets of 7 repetitions/session) (Kowalchuk & Butcher, 2019). Aerobic interval training improved aerobic fitness, blood pressure and body composition. Although flywheel leg press training showed no improvements in participants' aerobic fitness, blood pressure and body composition, there were notable increases in quadriceps muscle strength & quality of life and decreases in low density lipoprotein and total cholesterol (Bruseghini et al. 2015).

Sanudo et al. (2019) compared the effects of a flywheel training group versus a non-training group, on mobility, postural stability, power and balance. The study consisted of 18 healthy older adults averaging age 64. The flywheel group showed increases in mobility, muscle power and balance when compared to the non-training group. These results were achieved after 6 weeks of training 3 times/week, 4 sets of 9 repetitions using squats. The increases in balance led to a decreased risk of falls by improving postural stability (Sanudo et al. 2019; Kowalchuk & Butcher, 2019). In light of the above, eccentric flywheel overload training can be identified as an effective method for strength and functional performance improvements. Although still debated (Vicens-Bordas et al., 2018), mounting evidence (Maroto-Izquerdo et al., 2017) suggests that there is a possibility of flywheel training to yield greater increases in strength and power when compared to traditional resistance training. Based on the identified gaps in the literature we sought to directly compare eccentric flywheel overload training to traditional resistance training and their influences on muscle strength, muscle thickness, body composition (lean/fat mass) and functional performance using compound movements (i.e. squats) in healthy older adults. We believe that this study will help bring some clarity to the two methods of training highlighted above and determine whether compound movements such as squats can be effective for improving muscle strength, muscle thickness, body composition (lean/fat mass) and functional performance in healthy older adults.

Conclusion

Having established the deleterious effects of aging, several methods have been used and suggested as suitable ways to combat these changes i.e. loss of muscle strength, power and even functional performance. Eccentric Flywheel Overload Training and Traditional Resistance Training are suitable methods suggested by literature. There is a possibility that in terms of improvements in strength, power and functional performance the Eccentric Flywheel Overload Training might be a preferred option. This is not to say however that Traditional Resistance Training should not be used. It might be preferable for strength/conditioning coaches alongside other fitness and health professionals to use eccentric flywheel training in older adults, as previous research in this area has revealed that optimum gains in strength, power and lean muscle mass could be achieved. Regardless, further research still needs to be done to compare and fully understand the major differences and advantages between both training methods.

3.0 CHAPTER THREE: METHODOLOGY

3.1 Research Design

A parallel group randomized controlled trial (RCT) design was used for this study, whereby participants where stratified by age, sex and physical activity, then randomly assigned to one of two training groups: EFOT or TRT group evenly. This study was approved by the University of Saskatchewan Research Ethics Board.

3.2 Eligibility Criteria/Recruitment

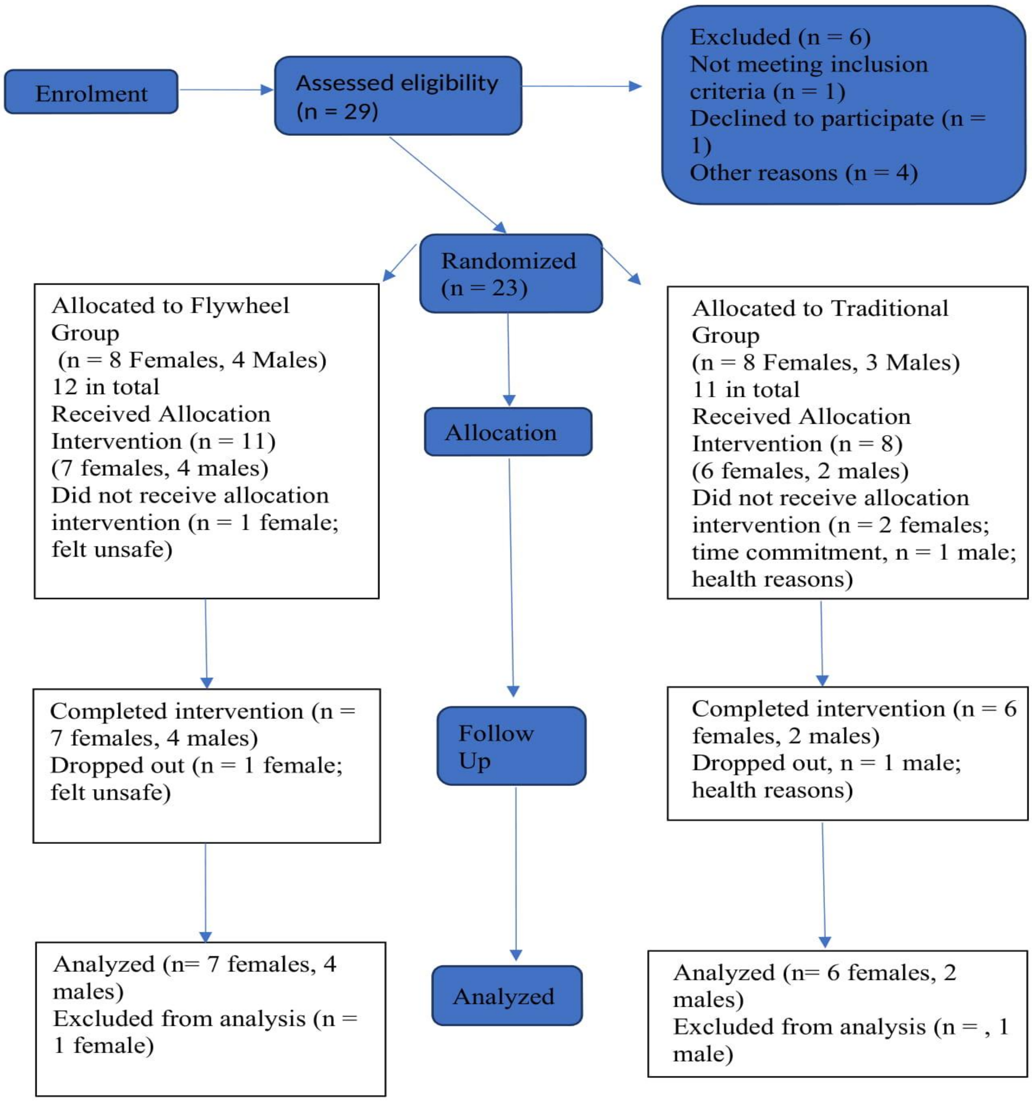
Twenty-three (7 males, 16 females) untrained (individuals who had not engaged in any regular or, systematic training program in the previous 3 months) but active, healthy older adults (55 and above) were recruited from the community. Recruitment was done through posters placed in the city of Saskatoon recreational facilities, various University College bulletin boards, a PAWS advertisement, gyms, care homes, offices of doctors and leisure centers. The sample size calculation we did had estimated 18 participants as an ideal number. This was achieved using a G power statistics software with an effect size of .30, level of significance .05 and 80% power. We anticipated a 20% drop out rate and decided to recruit more participants.

3.3 Consent Process

Having identified a number of participants interested in the study, the researcher sent out emails to each participant with details on the purpose of the study, the procedures to be undergone and potential risks and benefits associated with participating in the study. They were also informed about their rights and the option to withdraw anytime during the study. Once participants read and fully understood the study, they were asked to complete the consent form which was sent back to the student researcher. These consent forms were also provided to participants on the first day of the screening session (See forms below; appendices A-J).

3.4 Settings and Location

The testing and training sessions took place at the University of Saskatchewan (School of Rehabilitation Sciences and Williams Building) and Synergy Strength Cross fit gym respectively, Saskatoon.



Participant Flow Chart

Figure 3.1: Diagram showing participant flow

3.5 Stratification and Random Assignment Process

The randomization and stratification process was conducted by the Principal Investigator using a computer-generated list of random numbers (Microsoft Excel), who had no involvement in the testing procedures and training program. Participants were stratified by age (decade; 55-65, 66-75, etc.), sex and physical activity. Physical activity was ranked low, moderate and high using Canadian Society for Exercise Physiologists (CSEP) guidelines (2017). Participants were also asked to fill out the International Physical Activity Questionnaire (IPAQ). Participants received their allocations after the familiarization phases, just before commencement of training.

3.5.1 Enrolment and Flowchart

In total, 29 participants (Figure 3.1) were assessed for eligibility. During this period, the researcher contacted each participant individually and asked background questions indicated in screening phase 1 below. Six participants were excluded from the study after being assessed. Of the 6 excluded, 1 did not meet the inclusion criteria. Another participant declined to participate as the times for the intervention study were not feasible for her. The remaining participants were excluded for other reasons.

3.6 Screening

Phase 1 (over the phone): Participants were called and assessed for inclusion and exclusion criteria. Preliminary information on health history (likely concerns) was obtained alongside physical activity level and age. Participants were excluded from the study if they had any health concerns that could be a potential issue for them during the course of the study, were under the set age limit or had no physical activity levels whatsoever. In this study the researcher defined health concerns as heart disease, lung disease, diabetes or bone/joint problems- for example, previously diagnosed osteoporotic, fragility fracture within the past 2 years, joint arthritis with pain present daily and causing limits to functional activity, presence of joint replacements or presence of an acute injury in the past 6 months.

Phase 2 (Face to Face; Health Sciences Building): Participants came in and had a one on one encounter with the researcher. Here, the participants were asked to fill consent forms, International Physical Activity Questionnaires and Get Active Questionnaires (CSEP, 2017) were handed out to confirm the current physical activity levels, health status of the individual and occurrences over the past 6 months. This phase had a time commitment of 2 hours. Adequate rest was provided between tests that required more physical exertion. The following tests were conducted at the School of Rehabilitation Sciences; muscle thickness, knee extension, incremental shuttle walk test, 30s sit to stand, functional reach test and up and down stair climb power test.

3.7 Outcome Measures

These measurements were taken at baseline and after the 16-week intervention program. The variables assessed included muscle thickness of the quadriceps (more specifically, vastus lateralis) using ultrasound imaging, body composition using a dual energy X-ray absorptiometry, and muscle strength in the quadriceps using a knee extension exercise on an isokinetic dynamometer, focusing on the isometric, concentric and eccentric contractions. Strength tests were also assessed on other compound exercises like bench press, back squat and deadlift. The functional performance of these individuals was also assessed pre and post. This included the incremental shuttle walk test, functional reach test, 30s sit to stand test and the up and down stair climb power test.

3.7.1 Ultrasound (Assessing Muscle Thickness)

For the quantitative measurement of the muscle thickness, a LOGIQ e BT08 GE Healthcare Scanner (GE Medical Systems, Milwaukee, Wisconsin, USA) with an 8-12 MHz linear array (38 mm) transducer was used.

Participants (Figure 3.2) were positioned on a bed in a supine position. Once the participants were in a comfortable position, they were then told to identify their dominant leg (contralateral leg could be extended or flexed), referred to as the preferred leg used to kick a ball. For this research we focused on the vastus lateralis for one major reason. Out of the four heads of the quadriceps, it is the most powerful muscle with the highest contribution for force generation during walking (Ticinesi et al. 2018). There is a possibility that this is linked to a larger pennation angle than other muscles (Lieber, 2000), making it ideal for measurement by an ultrasound device. For this study, the researcher used the Anterior Superior Iliac Spine (ASIS) as a landmark and this was done in consideration of participants that had greater fat mass (Martin et al. 2017). Measurements were drawn from the ASIS to the base of the patella (dominant leg). Participants were instructed by the researcher to feel for their hip bone and then trace inwards (medially) until they contacted their iliac crest. Once identified, the researcher asked for permission to palpate and confirm the right point (ASIS). Landmarks were labelled with a permanent marker for easier identification.

Once the landmarks (ASIS & base of patella) were identified, the researcher then used a flexible tape measure to measure the proximal-distal lengths between the landmarks; this was assumed to be the vastus lateralis (VL) length. Having done that, the researcher then measured and marked 65% of the VL (Figure 3.3), starting from the ASIS. According to Ticinesi et al.

(2018), the 65% point of the VL is the site most free of vessels and presents almost parallel aponeuroses, making muscle thickness (MT) measurements more reliable. Following this, the researcher then took the midpoint between the 65% point of the vastus lateralis and the lateral part of the thigh. Measurements were taken down and the marked points were used for both pre and post-tests. Images were taken using a probe in both longitudinal and cross-sectional points to allow for a wider range of view. Generous amounts of gel were applied by the researcher to avoid incorrect reading and excessive pressure being used. During data collection the researcher also adjusted the probe, focus and gain to ensure that high quality images were captured. The ultrasound reading took about 10-15 minutes for each participant. This measurement was taken prior to engaging in any activity that required exertion like the knee extensions. This was to avoid error in our measurements. A systematic review conducted by Nijholt et al. (2017) revealed that the ultrasound is a reliable and valid tool for assessing muscle size in older adults. In their review they found the highest Intraclass correlation coefficient scores for vastus lateralis, rectus femoris, upper arm anterior, and the trunk (ICC= 0.72 to 1.000).

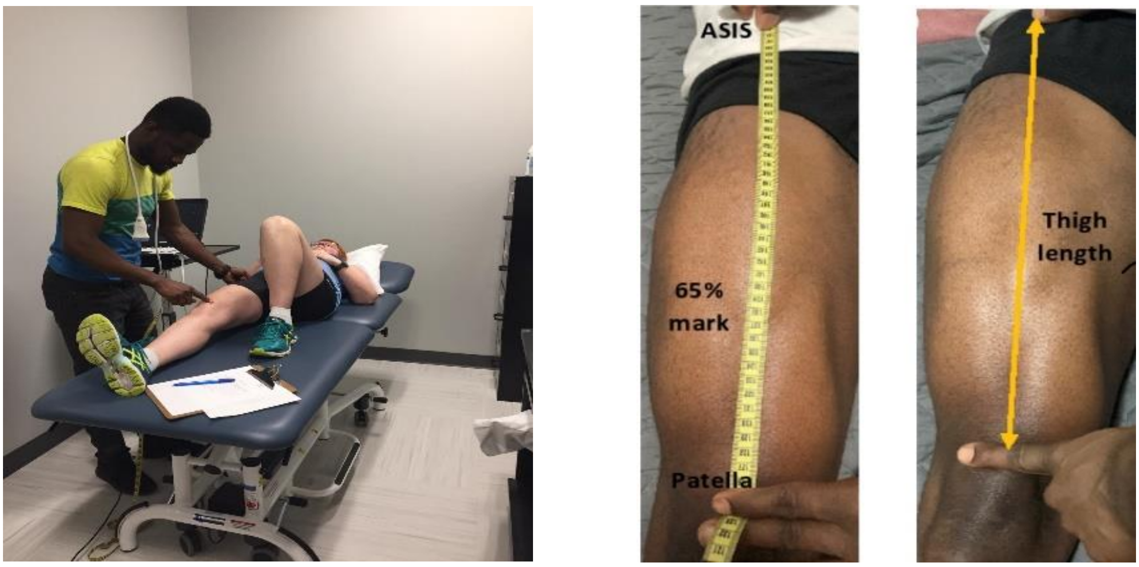
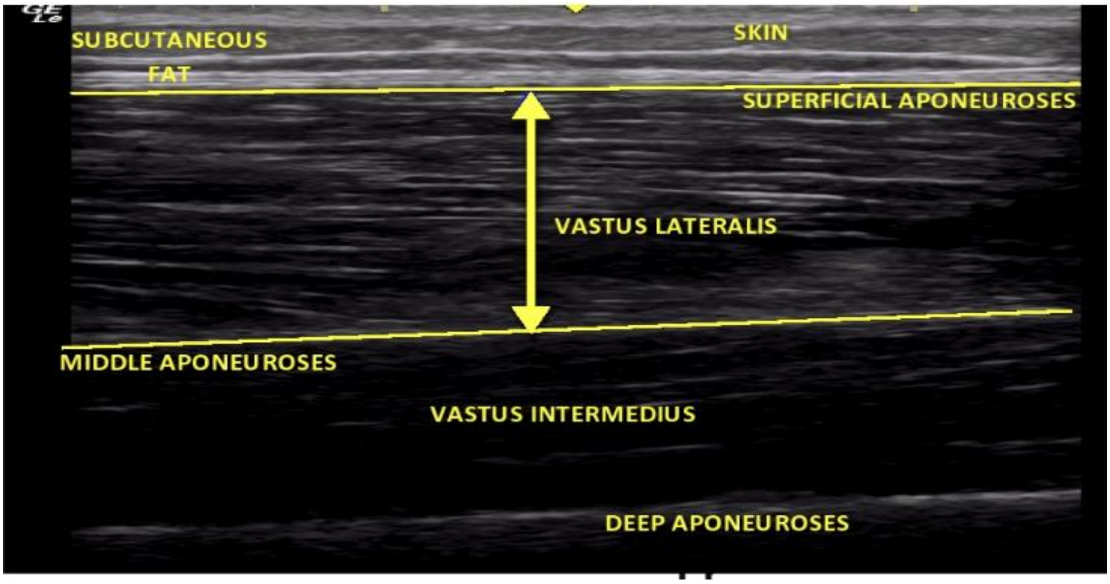


Figure 3.2: Picture showing the measurement of muscle thickness using an ultrasound.

Pre-Test



Post Test

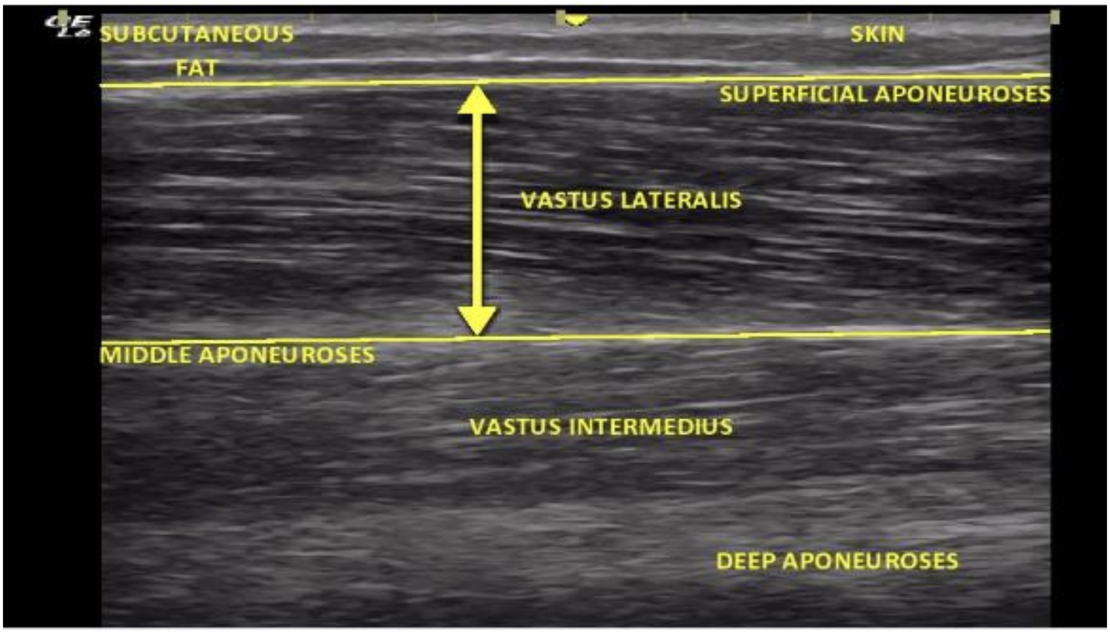


Figure 3.3: Picture showing an ultrasound measurement of the vastus lateralis from pre to post

3.7.2 Isokinetic Dynamometer (Humac Norm Testing/Rehabilitation System; Computer Sports Medicine Inc. Stoughton, MA)

The Isokinetic Dynamometer was used to measure the quadriceps strength using knee extensions. For the test, participants had to do three types of contractions: isometric, concentric and eccentric. Participants were required to seat in an upright position at 85° hip flexion from anatomical position. Adjustments were made according to manufacturer's guidelines (CSMI, 2009) to ensure that participants were comfortably positioned. The dynamometer's power shaft was aligned with the lateral epicondyle of the femur which in simple terms is the center of the knee joint. The resistance pad was placed on the distal two third of the tibia. Having done this, the trunk, mid-thigh of dominant leg and lower portion of the same leg (slightly above the medial malleolus) were stabilized with belts. The anatomical zero point was identified by having the client fully extend the knee (Rezaei et al. 2014; Duarte et al. 2018). For our study, the limit for extension and flexion (range of motion) of the knee joint was 10° and 85° respectively (Rezaei et al. 2014). These range of motion limits were used to compensate for individuals who couldn't fully extend to 0° or flex to 135°. The position of each participant, including the seat base, seat back, and length of lever arm was recorded during the screening phase (pretest) and was reused during the post test for reliability. For each contraction participants were instructed to hold on to the handles on both the left and the right sides of the seat.

Each participant had to complete a standardized warm up of knee extensions, 10 repetitions at 50% effort, after which the researcher assessed the isometric contraction. Participants were required to do 3 practice reps at 50%, 70% and 85% of maximal effort respectively. Contraction speeds (velocity) for both concentric and eccentric portions of the knee extension exercise were set at 60°/s (Jenkins et al. 1984; Dvir, 2004; Raj et al. 2012; Rezaei et al. 2014). The selection of this slower velocity was based on Hill's (1938) theory on the force-velocity relationship, indicating that at a slower/lower velocity muscles can generate a higher amount of force and vice versa. Following the practice reps, 3 maximal reps at a 100%, with 1-minute rest in between each rep were assessed. At the start of the test, the leg was moved to 60 degrees (Figure 3.4) to allow for a better leverage angle. Having successfully completed the isometric reps, each participant also had to do 5 practice and 3 maximal reps for the concentric muscle action. The participants were required to perform 3 practice reps at 50%, 75% and another 85% of maximal effort, making a total of 5 repetitions. The last muscle action on the dynamometer was the eccentric action. Here, the researcher raised the leg to be parallel to the floor (so in essence a fully extended leg), which was suspended by the dynamometer. At this point when instructed by the researcher, the participants were told to push up against the pad to trigger the dynamometer, which would then actively start pulling the leg down. Participants were told to try and resist being pulled down but also to make sure that their leg was properly guided back to the 90 degree position. Similar to the concentric action, participants were required to perform 3 practice reps at 50%, 75% and 85% of maximal effort, making a total of 5 repetitions. The Isokinetic knee extension test took between 30 to 45 minutes for each participant. Reliability and validity for using the isokinetic knee extension to assess quadricep muscle strength was identified using values reported by Andrade et al. (2013). They indicated that the results from the study were reproducible (eccentric: 0.95-0.97; concentric: 0.95-0.96; isometric: 0.93-.96).

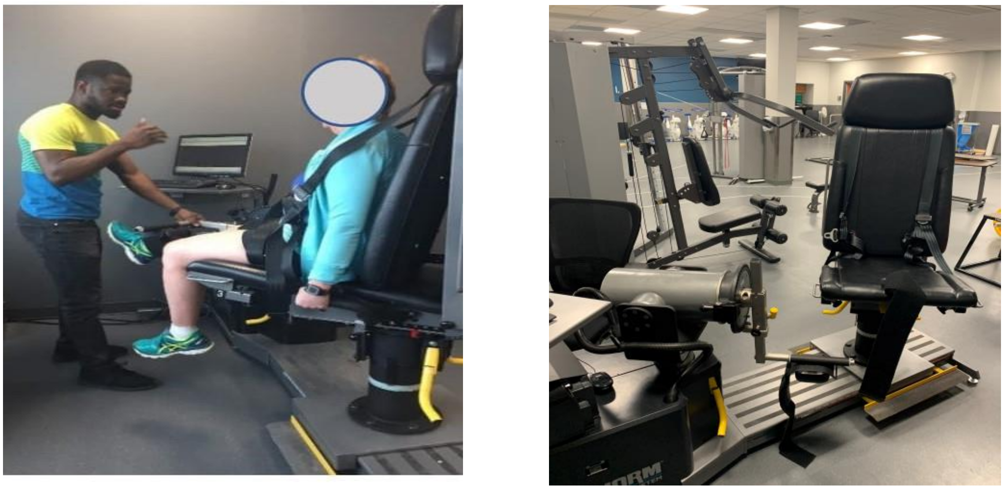


Figure 3.4: Picture showing the measurement of muscle strength in the right quadriceps using a knee extension exercise on an isokinetic dynamometer

3.7.3 Body Composition Scan

The DEXA scan took place at the basement of the Williams Building, University of Saskatchewan, the following week after the testing session at the School of Rehabilitation Science. Participants' whole-body composition (Figure 3.5) was assessed with dual energy X-ray absorptiometry (DXA) in array mode (QDR Discovery Wi, Hologic, Inc., Bedford, Md.) using QDR software for Windows XP (QDR Discovery) to assess the following: lean tissue mass and fat mass. Participants were required to lie in a supine position and stay as still as possible (relaxed). It was recommended that they wear comfortable clothing without any metal or jewelry. The scan took approximately 15 minutes for each participant. The DEXA scan has been shown to be a reliable and valid method for measuring body composition. Glickman et al. (1985) indicated that more specifically, the DEXA scan showed high reliability in determining total mass, fat mass, and lean body mass with intraclass correlations of 0.94, 0.97 and 0.89 respectively.

Figure 3.5: Picture showing the Dual Energy X-ray densitometer. Discovery X-ray Bone Densitometer, manufactured by Hologic Inc.

3.7.4 Functional Tests

As part of the phase 2 screening process, the researcher assessed the functional capabilities of each participant. These tests were used as a result of their reliability in determining the functional capabilities in older adults in other studies (Duncan et al. 1990; Dyer et al. 2002; Raj et al. 2012; Millor et al. 2013). Participants performed a battery of four tests (Raj et al. 2012) highlighted below:

Test 1: The incremental shuttle walk test (ISWT; Dyer et al. 2002) is a maximal and progressive test that was established to assess the aerobic and functional capacity of individuals. It involved a 10-meter shuttle course with cones at both sides, where individuals were expected to walk at a steady pace, back and forth along the course until they reach exhaustion. It was controlled by beeps and was expected that at the time of the beep the individual should have gone around the cone at a certain end and be heading to the cone at the other end. The end of a shuttle was indicated by a single beep and the triple beeps indicated an increase in walking speed. Participants were told to stop when they felt they couldn't go on any longer or if they felt any discomfort whatsoever. This test took approximately 30 minutes for each participant. The ISWT has been shown to be a valid and reliable test for assessing maximal exercise capacity in individuals with chronic respiratory diseases. Intraclass correlation coefficients ranged from .76 to 0.99 (Parreira et al. 2013). According to Granger et al. (2015), the ISWT is a promising test for assessing functional exercise capacity in lung cancer.

Test 2: The functional reach test (FRT; Duncan et al. 1990) was included in the study to assess the balance as well as functional mobility of participants. Participants were instructed to stand next to, but not touching, a wall and position the arm that is closer to the wall at 90 degrees of shoulder flexion with fingers pointing forward (the longest finger i.e. the middle finger was used to take the readings). The starting position was marked with a tape on the wall, after which participants were then asked to reach as far forward as they could without taking a step, leaning against the wall or even raising their heels. The point where the participant reached up to was marked and then the researcher measured and recorded the distance between the start point and end point. Three trials were taken, and the average was found. The functional reach test took approximately 5 minutes for each participant. According to Otao et al. (2014) the functional reach test has been confirmed to be a valid and reliable test for assessing balance in older adults. The Intraclass correlation coefficient was 0.80.

Test 3: The 30 second sit-to-stand test (30s STS; Millor et al. 2013): was also performed by participants to assess lower extremity strength and functional mobility. Participants were required to sit and stand as many times as possible within a period of 30 seconds. An armless seat with a height of 43.2 cm was used for the study. The researcher instructed the participants to start in a seated position, with the back straight, arms crossed held close to the chest and feet shoulder width apart. Before the commencement of the test, the participants were asked to do a few practice repetitions to help get used to the action. At any given point, if the arms were used as a source of help the test was stopped immediately. The 30s sit to stand test took 2 minutes in total, including practice repetitions. Jones et al. (1999) reported excellent reliability and validity values for the 30s sit to stand test, indicating that this is a good test for assessing function in older adults.

Test 4: The Up and Down Stair climb power test (UDSCPT; Raj et al. 2012): was the last functional test used for the study to assess muscle power in seniors. Participants were expected to ascend and descend 10 steps with or without the use of railings as quickly as they could. It was important for both feet to make contact with the 10th step and the ground step in each trial. There were 3 trials and the average was found once the test was done. The researcher emphasized safety when ascending and descending the steps. It was important to go as quickly as they could while also avoiding any injuries. The protocol used in this study was similar to the one applied by Raj et al. (2012), with a slight variation. The researcher took times of participants from when they ascended the stair to when they came down, without a pause at the top. There was no distinction or separation in times between the ascending and descending portion. Up and down stair climb power test took about 5 minutes for each participant. Reliability and validity of this test was based off Jones et al. (2015) study. They reported Intraclass correlation coefficient of 0.99 which was considered to be high.

The researcher made sure to track each participant's heart rate and rating of perceived exertion using a heart rate monitor and Borg scale (Borg, 1982) respectively throughout the exerting tests (ISWT, 30s STS and UDSCPT), to ensure that they were will still within a safe range to continue the activities.

3.8 Supplementary Measurements

Once the testing sessions at the University of Saskatchewan were completed, participants were required to go to Synergy Strength, a cross fit gym where the training sessions were to take place. The tests below; Kbox power test, 4 RM back squat, deadlift and bench press were all performed at the end of the familiarization sessions. This was to make sure participants had some experience prior to being assessed. The Kbox power was assessed on a separate day, while the 4 RM tests (back squats, deadlifts and bench presses) took place on the same day with a minimum of 5 minutes rest between exercises.

3.8.1 Kbox Power test

After completing the standardized warm-up protocol (involving the same specific stretches every session), using standardized traditional resistance protocols published by the ACSM's Foundations of Strength Training and Conditioning (2012) and the kBox4 pro flywheel inertial loading system (Exxentric AB, Sweden) with a single 0.05kg/m^2 inertial flywheel attached, participants performed the kBox power test protocol. Firstly, participants were required to put on a harness (Figure 3.6) which was securely attached around the waist while the horizontal belt was secured on the lower back. The drive belt length was adjusted to allow for full

extension at the hips and knees without any slack in the belt. Participants were advised to maintain the same foot stance on the platform used for a traditional barbell back squat, ensuring that the width and position were the same. The kBox power test consisted of 6 total squat reps. Beginning from the bottom of the squat, the first 2 reps served as ramp-up reps to build momentum in the flywheel (1st rep~80% effort during concentric phase=standing up, 2nd rep = 100% effort), followed by 4 maximal (100%) effort reps. A minimum of 3 minutes rest was provided between maximal attempts to minimize fatigue. Participants were instructed again to maintain a consistent squat depth (either terminating eccentric phase when top of the thigh is parallel to floor or below) for each squat repetition. Squat depth however was relative to each participant's range of motion. Participants that felt pain or restrictions at a certain depth were advised to stop at a more comfortable squat depth. The researcher was there at all times, ensuring the safety of participants and assisting in ideal exercise positions.
Construct validity and test-retest reliability of the kbox flywheel device was based on results from Bollinger et al. (2018) study. Their study revealed a good (r= ≥0.70) to excellent (r= ≥0.90) test retest reliability for all outcome measures except peak eccentric power for biceps. A limitation noted however, was that there were varied reliabilities between different lifts and exercise protocols

Figure 3.6: Picture showing a harness used during a kbox squat and a participant performing this exercise.

3.8.2 Barbell Back Squat Strength Test

After completing the standardized warm-up (involving the same specific stretches every session), using standardized traditional resistance protocols published by the ACSM's

Foundations of Strength Training and Conditioning (2012), participants continued to increase the load on the barbell (Figure 3.7) gradually until they could complete 4 full squat repetitions only. A true 4RM (multiple repetition maximum) test was used for this exercise and the bench and deadlift exercises as well. Multiple repetition maximum could be defined as the maximal weight which an athlete can lift 4 times with the correct lifting technique (Schlumberger & Schmidtbleicher, 2000; Dohoney et al. 2002; Baechle et al. 2008).

According to previous research, 1 RM does not correctly specify loads for strength training (Marschall, Fröhlich, 1999; Shimano et al. 2006) which has led to suggestions of "proper alternatives" (Gail & Kunzell, 2014) like the multiple-repetitions maximum. The warm-up exercises were specific and involved neck stretches, hip mobility stretches, quadriceps/hamstring stretches and squats. A minimum of 3 minutes rest was provided between maximal attempts to minimize fatigue. Participants were instructed to maintain a consistent squat depth (either terminating eccentric phase when top of the thigh is parallel to floor or below) for each squat repetition. Where weights were slightly too heavy, spotters were placed on both sides of the barbell to assist the participant. Gail & Kunzell, (2014) indicated in their study that the multiple repetition maximum strength test is a reliable method of assessing strength in recreational athletes. They reported high intraclass correlation coefficient of 0.90. This was also reported by Taylor & Fletcher, (2011) involving an 8-repetition maximum strength test on men and women. Similarly, a high intraclass correlation coefficient was observed (r=0.90). This reliability and validity was used for all the other (deadlifts and bench presses) 4RM strength tests.

Figure 3.7: Picture showing a traditional barbell back squat

3.8.3 Deadlift and Bench Press Tests

Standardized warm-ups (ACSM's Foundations of Strength Training and Conditioning, 2012) were also completed for the deadlift and bench press (Figure 3.8). Warm-ups specific to deadlifts included; hip hinges, hamstring stretches and back stretches, while warm-ups specific to the bench press included; chest stretches, arm stretches and push-ups. Prior to this point, participants were shown how to perform each exercise and also given ample time to practice. It was emphasized that for both exercises male (20.4kg) and female (15.9kg) barbells should be used. For participants that had issues with those weights, a 6.8kg barbell was introduced and this was progressed over time. Participants continued to increase the load until they could complete a maximum of 4 repetitions only. A coach was with them at all times to ensure the proper form was being used to exercise.

Figure 3.8: Picture showing participants doing deadlifts and bench presses respectively

3.9 Exercise Protocol

A familiarization session was initially set up for two weeks, which was then extended to three weeks to help participants gradually get more comfortable doing exercise routines and more specifically, to work on the exercise techniques that would be applicable to the training they were going to be engaged in over a couple of months. In the long run this was also meant to reduce the amount of learning to be done during the training. They were required to come in 3 times a week: Mondays, Wednesdays and Fridays. Load and repetitions for this period were minimal (i.e. between 2-3 sets of 6-10 repetitions). In the last week of the familiarization phase, the researcher performed additional baseline tests; Kbox power test, back squat strength test, bench press strength test and a deadlift strength test.

After successful completion of the familiarization sessions, the training started in full. The training went on for 13 weeks on Mondays, Wednesdays and Fridays. Training times were from 7 to 8pm or 8 to 9pm. Participants were asked to consistently attend each training session and to stick to the time slot assigned to them. Prior to each training session, a coach took the participants through standardized warm up procedures which included the following exercises: neck tilt (forward and side to side), shoulder stretches, trunk rotation, hamstring stretches and squats.

In the first few weeks of the training, the coaches had participants start off with higher reps but lower weights (2X6, 2X10 or 3X10, depending on the exercise being performed at the time). Gradually, as participants got comfortable, the amount of resistance increased thereby leading to a reduction in the reps but an increase in the number of sets. The target was to progressively overload participants until they reached their 4-repetition maximum. The researcher was at all training sessions, supervising and ensuring that everything went on smoothly. Participants were encouraged to keep track of their progress by documenting how much weight they lifted at each training session. This also helped the researcher in keeping an eye on the compliance rate of each participant.

3.9.1 Eccentric Flywheel Overload Training Group

For the EFOT group, squats were performed using the KBox flywheel ergometer building toward all out in 4 sets of 6 repetitions (4x6) while deadlifts and bench presses were performed using barbells. The EFOT group started training using approximately 60-70% exertion (6-7/10 on the modified BORG scale) for the first week and progressed to 100% (10/10) on the third week following the end of familiarization. Inertial load was set at 0.05 kg/m^2 for the first couple of weeks and progressed as tolerated using a linear progression. The first 3 weeks after familiarization focused on building the level of exertion. After the build-up phase, the researcher introduced the Eccentric Overload Squat technique, where participants were expected to start in a half squat position, stand fully erect, immediately drop down into a squat and let the flywheel pull. At this point, the rate of exertion was reduced to 80% until the participants were used to the new technique. Training programs were individualized for the EFOT group. For each session, the researcher made sure participants took notes of their maximum weight per week and was advised by the coach/researcher to increase the weights when they felt comfortable. Exercises were progressed every week.

3.9.2 Traditional Resistance Training group

For the TRT group, squats, deadlifts and bench presses were performed using a barbell (straight, safety squat, or trap bar) building up to a heavy set of 6 repetitions each session. The TRT group also used a linear progression after successful 4x6 repetitions at a given load. Like the EFOT group, participants started using 60-70% exertion for the first week and progressed to 100% on the third week at the end of the familiarization session. Each training group had a coach assigned to ensure the exercises were done properly and to reduce any chances of injury, especially when the weights became too heavy. Training programs were individualized for the TRT group. For each session, the researcher made sure participants took notes of their maximum weight per week and was advised by the coach/researcher to increase the weights when they felt comfortable. Exercises were progressed every week.

3.10 Statistical Analysis

The primary outcomes for this study were muscle strength (isometric, concentric, eccentric, 4RM squat, 4RM bench press, 4RM deadlift), muscle thickness and body composition (lean/fat mass) while the secondary outcome was functional performance (functional reach test, up and down stair climb power test, 30 second sit to stand and incremental shuttle walk test).

Sample size was justified using the G-power statistics software (version 3.1) based on a power of the test of 80% and statistical significance set at 5%. The power calculation of this study was based on muscle strength which is our primary outcome and the predicted effect size was .30. This value was used as it served as a more conservative estimate required for sample size generation (Schoenfeld et al. 2019). Thus, the estimated sample size for our study was 18 participants assigned evenly to each group stratified by age, physical activity level and sex (i.e. 9 per group-EFOT/TRT). Initially, we speculated a dropout rate of 20% and decided to recruit a higher number of participants (29) to adjust for the possible dropout rate. Q-Q plots and Mauchley's tests were used for verification of data normality and sphericity, respectively. A repeated measures factorial ANOVA [group (EFOT vs. TRT) × time (baseline vs. post-16 weeks)] was used. Effect sizes were also included for each outcome using partial eta squared generated from the tests of within-subject table and test of between subject table (Lakens, 2013). They were calculated by dividing the sum of squares of the effect by sum of squares effect plus the sum of squares error. According to Keppel et al. (1991), partial eta squared is preferred to eta squared when comparing effect sizes between groups. Scores of .2, .5, and .8 indicate small, medium and large effect sizes respectively (Cohen, 1988). Standard error bars were included in each graph. All statistical analyses were conducted using a statistical package (SPSS 24.0, Chicago, Illinois, United States) using a significance level of $p < 0.05$.

4.0 CHAPTER FOUR: RESULTS

4.1 Participant Demographic Data

Table 1: Participant demographic data

Group	N	M/F	Mean Age (years)	Mean Weight (kg)	Mean Height (cm)	Adherence
EFOT	11	4/7	63.2 +/- 7.8	83 +/- 13.7	168.3 +/- 6.9	87.4%
TRT	8	2/6	63.8 +/- 5.2	74.2 +/- 13	162 +/- 5.2	90.4%

The values in the table are means and standard deviations

EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

Note: There were no group x time interactions for any of the dependent variables; therefore, the following sections present only group and time main effects. In addition, there were no significant differences between group (EFOT and TRT).

4.2 Isometric Peak Torque

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in isometric peak torque. $F(1, 17) = 37.4$, $p < .001$. The pooled effect size (ηp2 = .6) for groups over time was medium for isometric strength. However, there was a small effect size (ηp2 = .2) between groups.

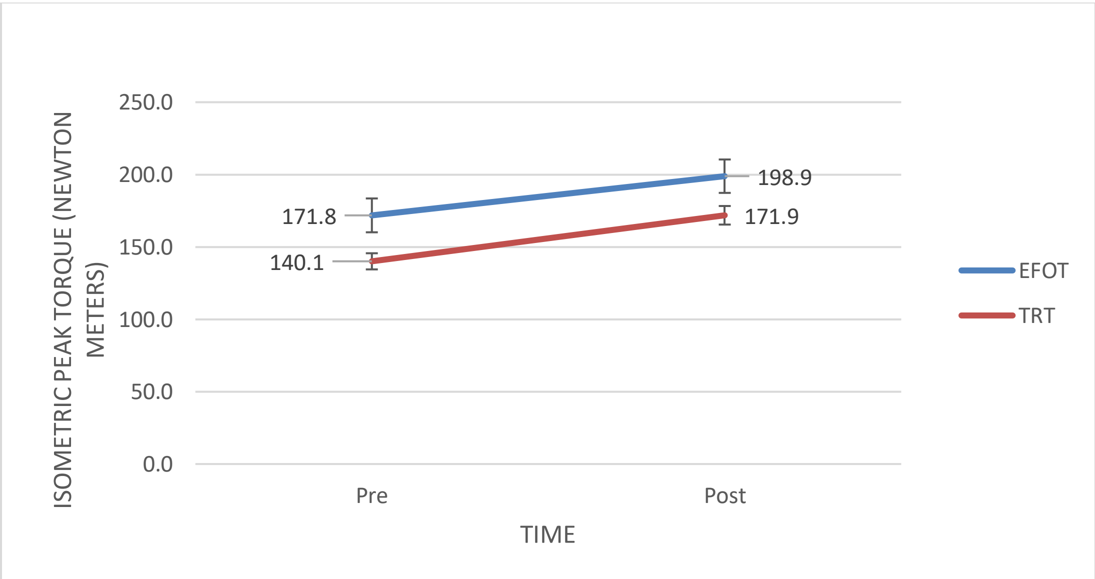


Figure 4.1: Line graph showing isometric peak torque from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.3 Concentric Peak Torque

The omnibus factorial ANOVA revealed that there was no significant main effect for time (pre and post), indicating that pooled scores from groups had similar effects on concentric peak torque over time with no improvements. $F(1, 17) = 3.5$, $p = .08$. The pooled effect size ($\eta p2$ = .17) for groups over time was small for concentric strength. Similar results were also observed for effect size between groups ($\eta p2$ = .06).

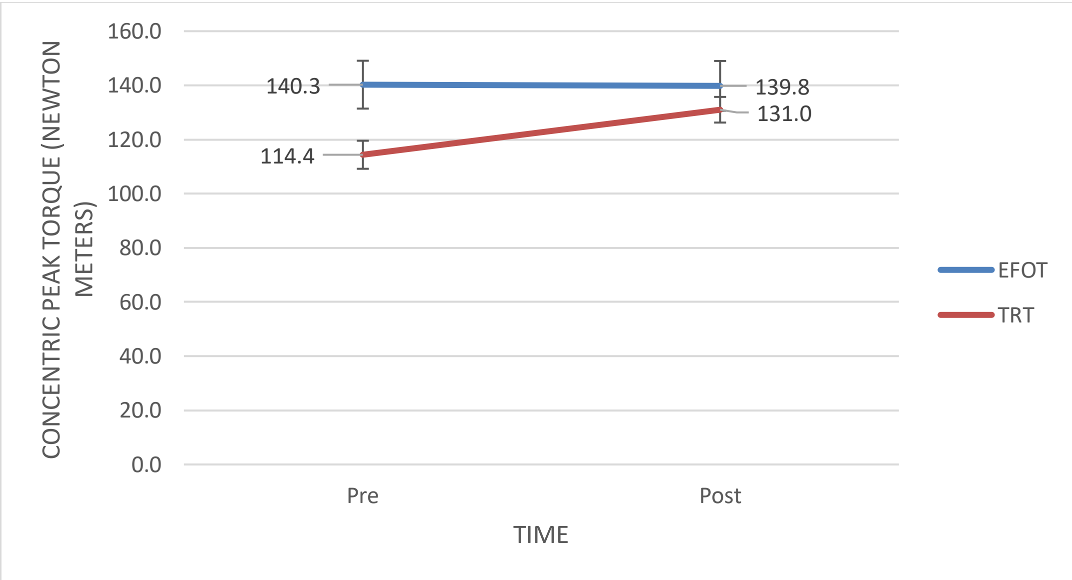


Figure 4.2: Line graph showing concentric peak torque from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.4 Eccentric Peak Torque

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in eccentric peak torque. $F(1, 17) = 20.12$, $p < .001$. The pooled effect size for groups over time was medium ($\eta p2$ = .5) for eccentric strength. However, there was a small effect size between groups ($\eta p2$ = .13)

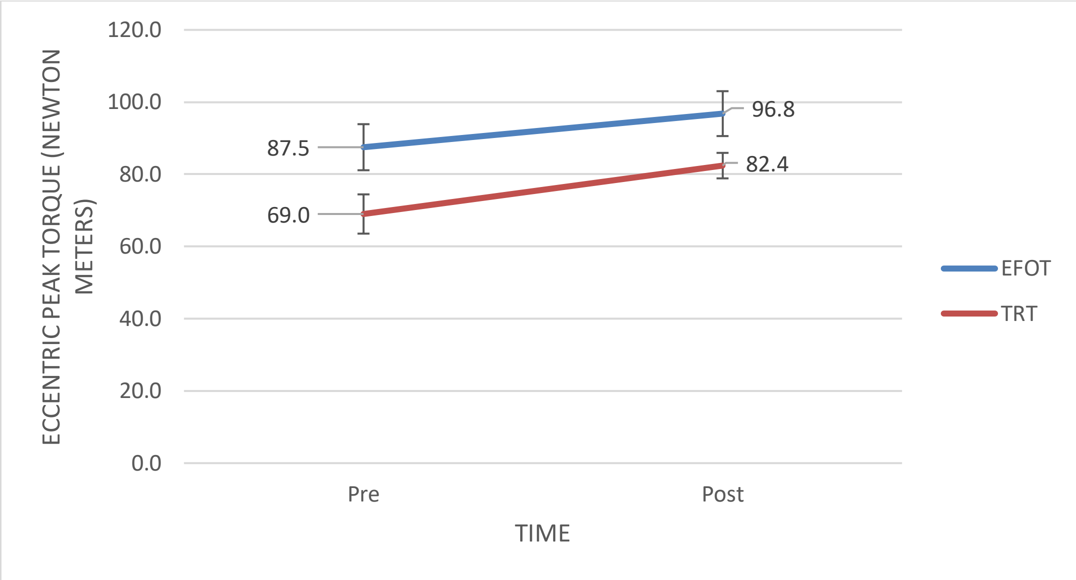


Figure 4.3: Line graph showing eccentric peak torque from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.5 Squat 4RM

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in 4RM squat strength. $F(1, 17) = 87.53$, $p < .001$. The pooled effect size was ($\eta p2 = .84$) large over time in groups for 4RM squat strength. The effect size ($\eta p2 = .03$) between groups however was small.

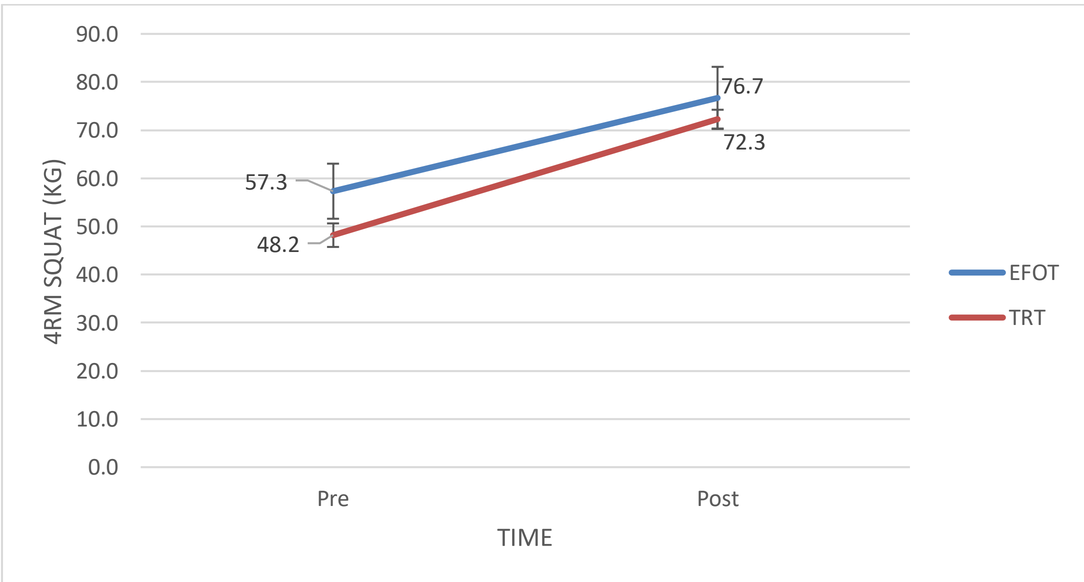


Figure 4.4: Line graph showing squat 4RM from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.6 Bench Press

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in 4RM bench press strength. $F(1, 17) = 36.52$, $p < .001$. The pooled effect size was ($\eta p2 = .68$) medium in groups over time for 4RM bench press. There was a small effect size ($\eta p2 = .05$) between groups.

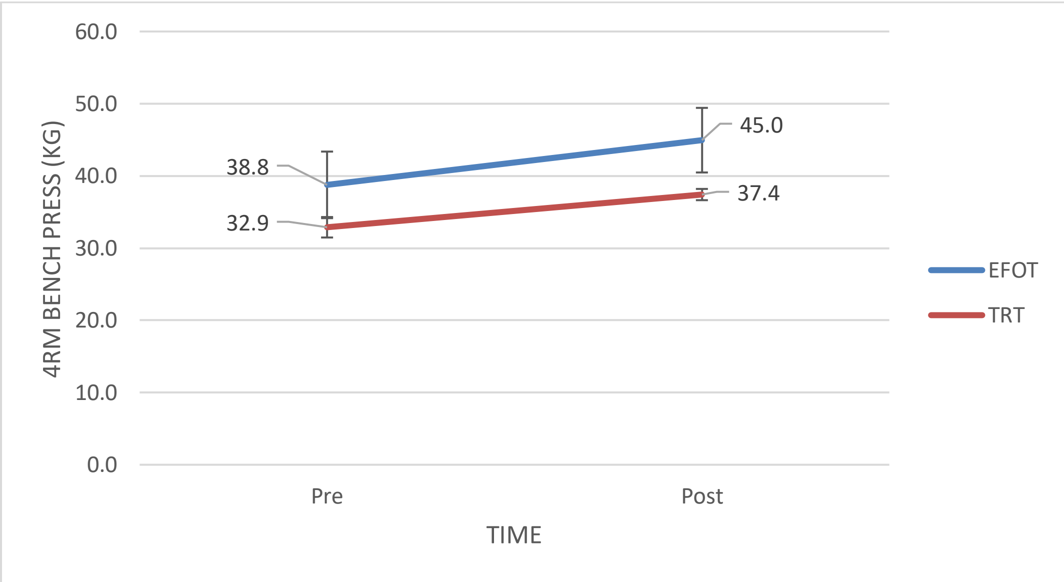


Figure 4.5: Line graph showing bench press 4RM from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.7 Deadlift

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in 4RM deadlift strength. $F(1, 17) = 102.82$, $p < .001$. The pooled effect size ($\eta p2 = .86$) was large in groups over time for 4RM deadlift strength. There was a small effect size ($\eta p2 = .08$) between groups.

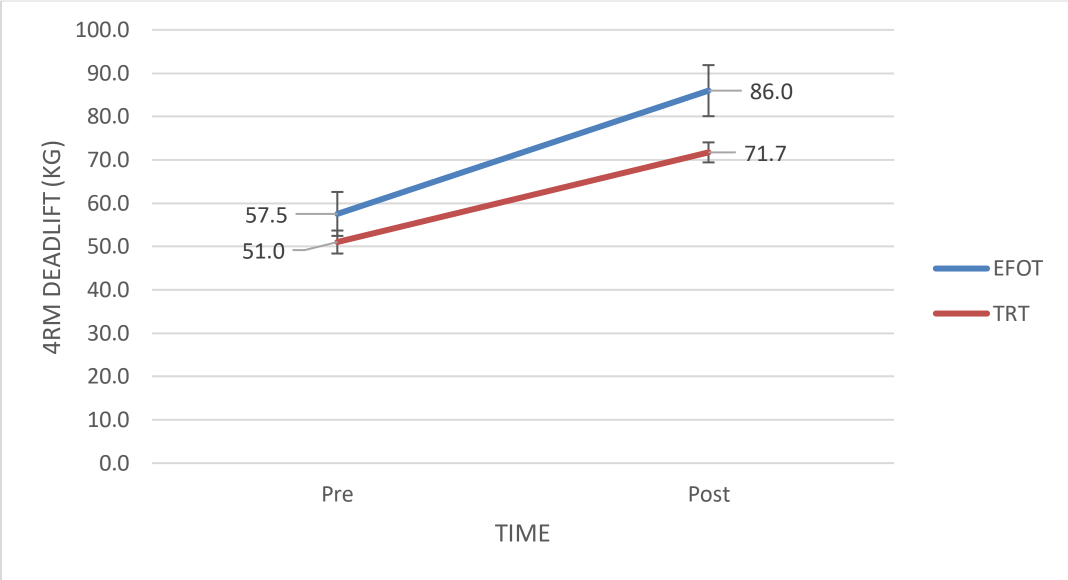


Figure 4.6: Line graph showing deadlift 4RM from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.8 Fat Mass

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in fat mass. $F(1, 17) = 18.05$, $p < .001$. The pooled effect size for groups over time was medium ($\eta p2 = .52$) for mass. There was however a small effect size between groups ($\eta p2 = .05$).

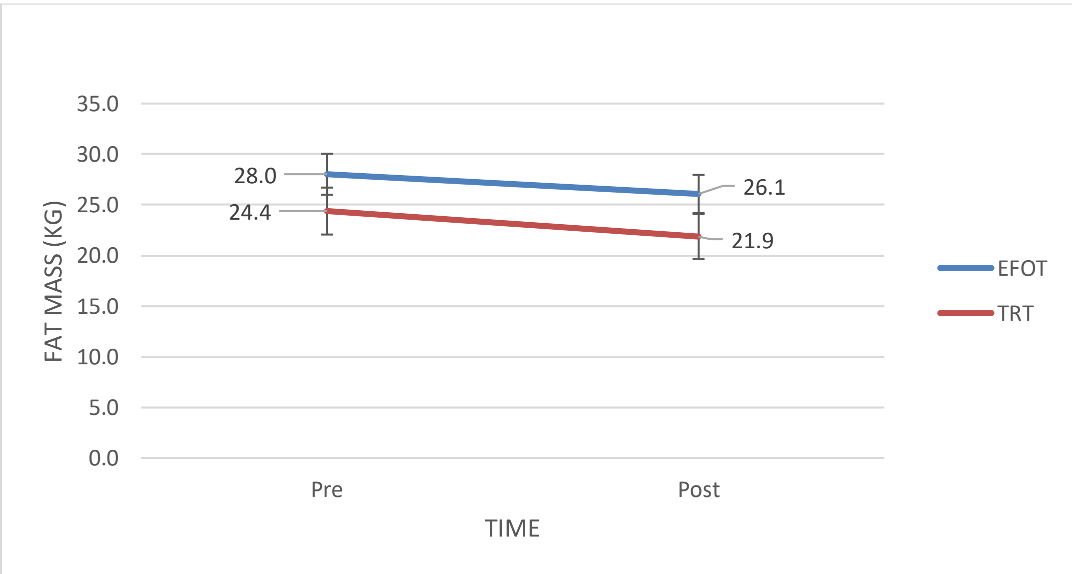


Figure 4.7: Line graph showing fat mass from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.9 Lean Mass

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in lean mass. $F(1, 17) = 21.94$, $p < .001$. The pooled effect size for groups over time was medium ($\eta p2 = .56$) for lean mass. There was however a small effect size between groups ($\eta p2 = .1$).

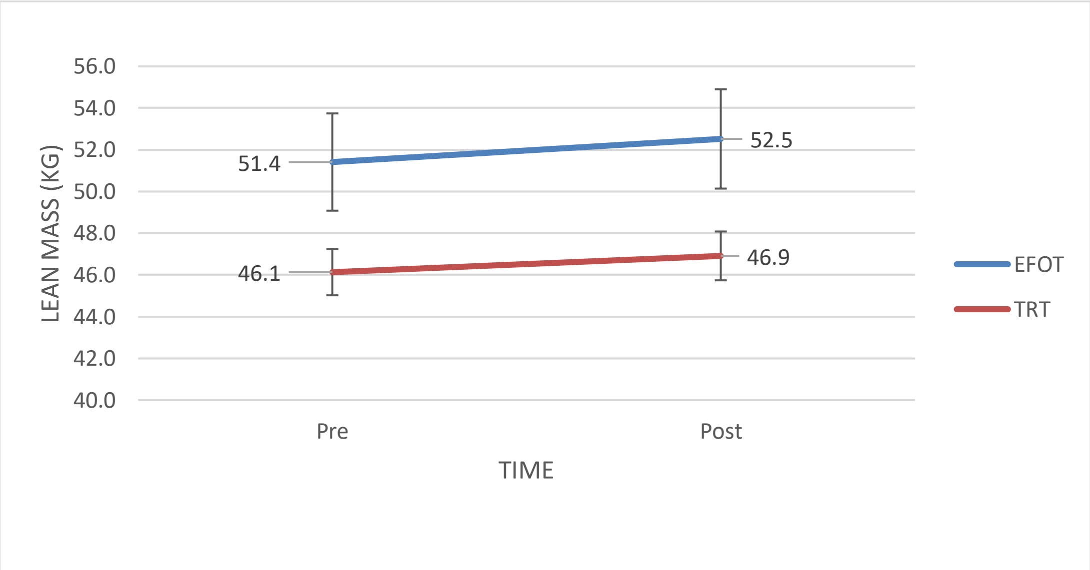


Figure 4.8: Line graph showing lean mass from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.10 Muscle Thickness

The omnibus factorial ANOVA revealed that there was no significant main effect for time (pre and post), indicating that pooled scores from groups had similar effects on muscle thickness over time with no improvements. $F(1, 17) = 3.90$, $p = .07$. The pooled effect size for groups over time was small ($\eta p2 = .19$) for muscle thickness. There was also a small effect size between groups ($\eta p2 = .02$).

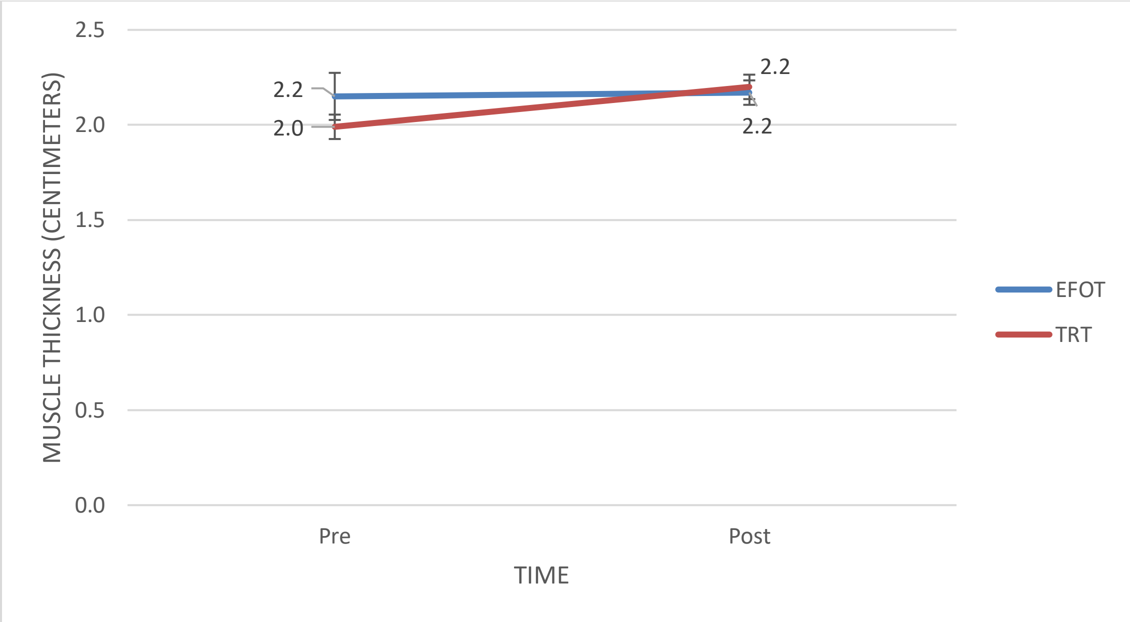


Figure 4.9: Line graph showing muscle thickness from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.11 30 Seconds Sit to Stand

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in 30s sit to stand performance. $F(1, 17) = 65.007$, $p < .001$. The pooled effect size was (ηp2 = .79) large in both groups over time for sit to stand performance. However, there was a small effect size (ηp2 = .007) between groups.

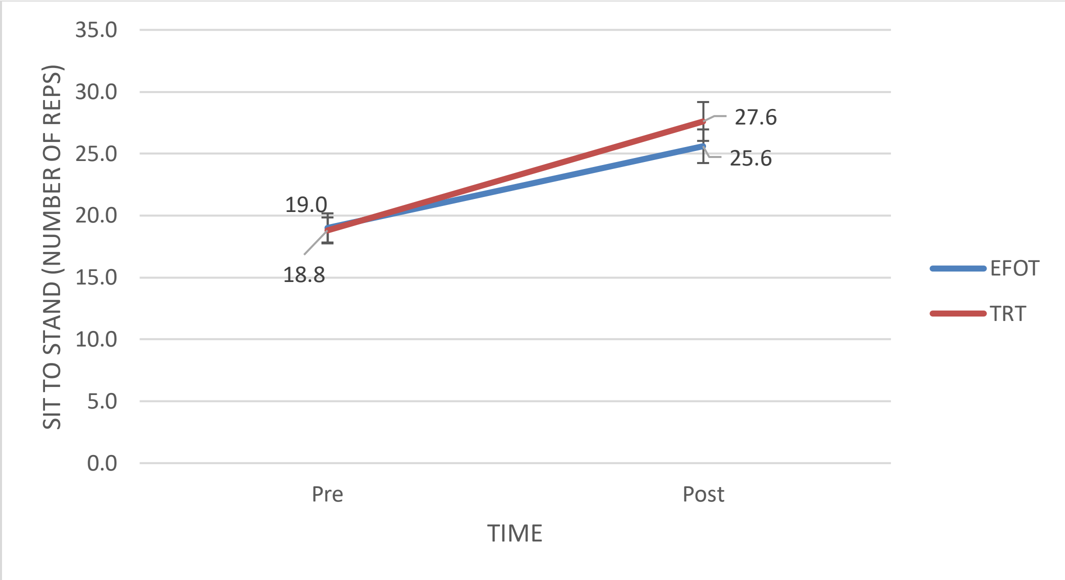


Figure 4.10: Line graph showing Sit to Stand performance from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.12 Functional Reach Test

The omnibus factorial ANOVA revealed that there was no significant main effect for time (pre and post), indicating that pooled scores from groups had similar effects on functional reach over time with no improvements. $F(1, 17) = 1.23$, $p = .28$. The pooled effect size ($\eta p2 = .07$) was small for groups over time for functional reach. There was a small effect size ($\eta p2 = .2$) between groups.

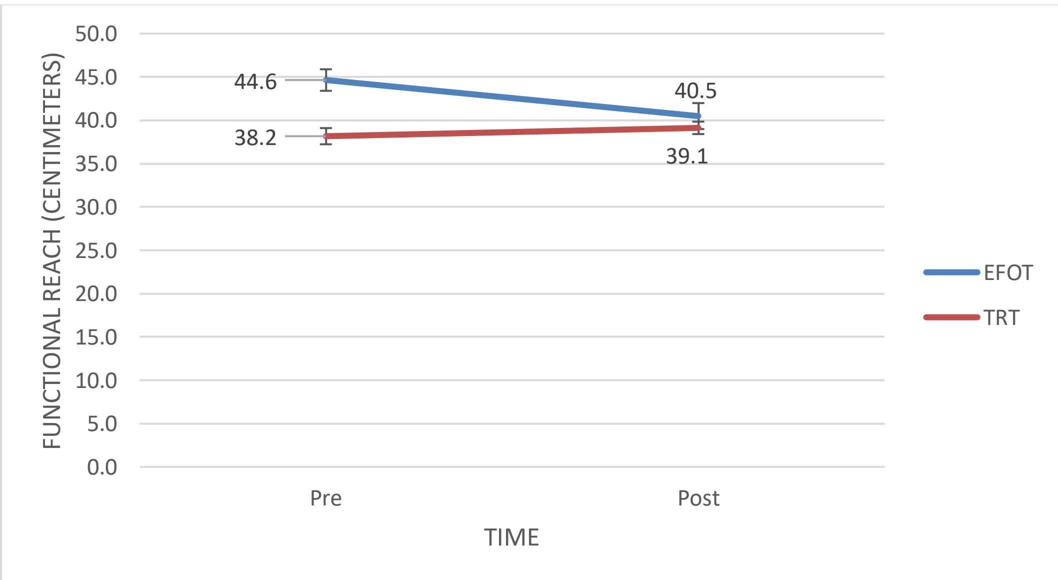


Figure 4.11: Line graph showing functional reach performance from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.13 Up and Down Stair climb Power Test

The omnibus factorial ANOVA revealed that there was a significant main effect for time (pre and post), indicating that pooled participant scores improved over time in up and down stair climb performance. $F(1, 17) = 4.88$, $p = .04$. The pooled effect size (ηp2 = .22) was small for groups over time for up and down stair climb power. There was similarly a small effect size (ηp2 = .12) between groups.

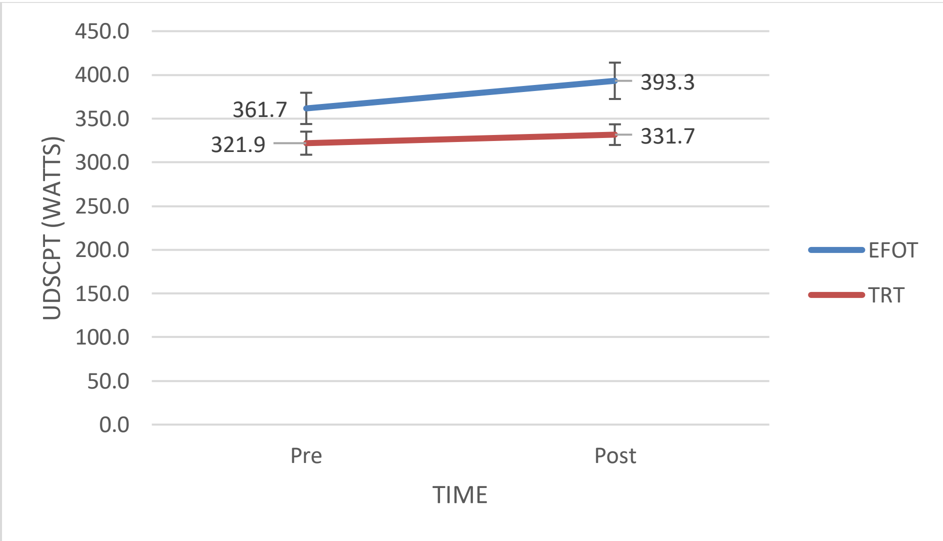


Figure 4.12: Line graph showing Up and Down Stair Climb Power test from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

4.14 Incremental Shuttle Walk Test

The omnibus factorial ANOVA revealed that there was no significant main effect for time (pre and post), indicating that pooled scores from groups had similar effects on incremental shuttle walk over time with no improvements. $F(1, 17) = 4.31$, $p = .054$. The pooled effect size for groups over time was small for incremental shuttle walk (ηp2 = .2). There was similarly a small effect size (ηp2 = .001) between groups.

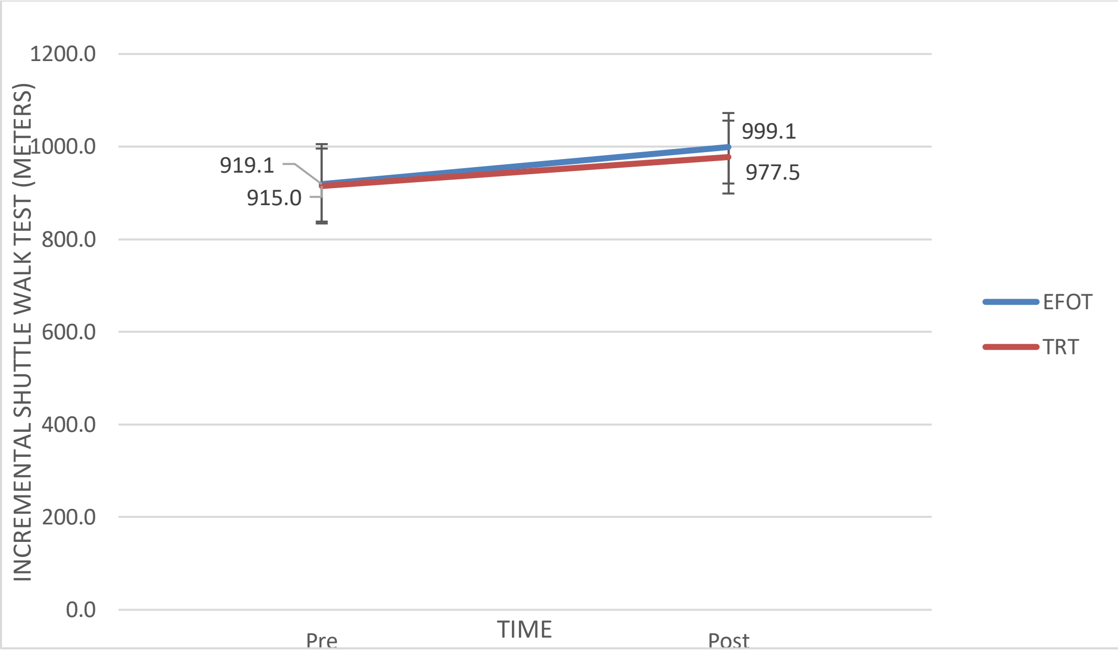


Figure 4.13: Line graph showing incremental shuttle walk performance from pre to post intervention. Standard error bars were used in the graph. EFOT refers to Eccentric Flywheel Overload Training while TRT refers to Traditional Resistance Training

5.0 CHAPTER FIVE: DISCUSSION AND CONCLUSION

5.1 Discussion

The main findings from our study revealed that both eccentric flywheel overload training and traditional resistance training had similar impacts on isometric strength, eccentric strength, 4RM squat strength, 4RM bench press strength, 4RM deadlift strength, body composition (lean/fat mass), and functional performance (30s STS and UDSCPT).

5.2 The primary hypothesis of this study was to identify whether eccentric flywheel overload training will result in greater increases in isokinetic knee extension strength, 4RM squat strength, 4RM bench press strength, 4RM deadlift strength, lean mass, and muscle thickness than traditional resistance training within a whole-body strength program.

The first outcome measure of interest was muscle strength. Our study revealed a main effect for time, indicating that EFOT and TRT groups improved over time in isokinetic knee extension strength (isometric- EFOT, 16%; TRT, 23% and eccentric- EFOT, 11%; TRT, 20%) and squat strength (EFOT; 34% and TRT; 50%). Recently, there have been quite a few studies comparing eccentric flywheel training and traditional resistance training (Maroto-Izquerdo et al 2017; Vicens-Bordas et al. 2018) in younger populations, but not as much in healthy (Kowalchuk & Butcher, 2019) older adults. One example in a healthy older population was a study conducted by Onambele et al. (2008). Individuals were randomly assigned to a flywheel group or weight-lifting group training knee extensors three times in a week for 12 weeks. Although not assessed in our study due to certain complications, Onambele et al. (2008) showed an increase of 28% in knee extensors peak power in the flywheel group with no changes in the weight training group. Increases in gastrocnemius tendon stiffness were also observed in both the flywheel (136%) and weight training (54%) group; however higher increases were identified in the flywheel group and these increases showed higher associations with improvements in postural balance. Symons et al. (2005) observed similar findings to our study in isometric and eccentric strength after a 12-week intervention program (3 times a week) in older adults, averaging age 73. A biodex system was used and the focus was to assess peak isometric and isokinetic (concentric and eccentric) knee extensor strength. Important to note however, is that the exercises utilized were different and in contrast to our study they saw improvements in concentric strength after the intervention. In addition, the results from our study contradicted those highlighted by Roig et al. (2008) in their systematic review on concentric and eccentric strength. The studies included in their review revealed that improvements were observed after resistance training in isometric, concentric and eccentric strength. The reason for lack of significant improvements in concentric strength observed in our study when compared to other studies is unknown. However, there is a possibility that since the isokinetic knee extension strength test using a dynamometer was quite different from the training protocol, participants might not have been neurally adapted to the knee extension test. The findings from our study contradict those found in a meta-analysis on eccentric flywheel training conducted by Petre et al. (2018). According to their review, eccentric flywheel training when compared to traditional resistance training yielded greater increases in strength and this was linked to the flywheel being able to allow for maximal resistance throughout the whole range of motion and in every single repetition in a set regardless of the internal and external moment arm. In addition, Caruso et al. (2005) and Bruseghini et al. (2015) revealed that younger individuals (.47% increase) have a higher chance of adapting to flywheel training than older adults (.07%) in terms of maximal strength; this might be one of the factors responsible for the limited increases associated with eccentric flywheel overload training in our study. The researchers suggested that this advantage might be due to the higher percentage of muscle mass in the younger population as it has been confirmed repeatedly that a decline in muscle mass accompanies aging (Brady & Straight, 2014).

Within the past decade, two studies involving older adults that had experienced stroke were conducted by Fernandez-Gonzalo et al (2014; 2016). The first study revealed that flywheel training using a flywheel leg press machine resulted in significant increases in eccentric isokinetic torque at 60 and 90 degrees/second and isometric leg press force ranging from 10-20%. This study however did not compare the flywheel training to traditional resistance training. The second study also showed that after engaging participants (16 men and 16 women) in an intervention for 6 weeks, involving flywheel supine squats, there were increases in muscle mass, muscle strength/power (although higher in men), squat and drop jump height. These findings are in contrast to the results from our study. Participants in this study were grouped into either a flywheel group or a control group (performing regular daily activities). Differences between studies could be related to several factors including the difference in exercises used, and differences in control group (traditional resistance training group vs. an active control group). Despite the abundance of existing research in favor of EFOT (Maroto-Izquerdo et al. 2017), a recent meta-analysis undertaken by Vicens-Bordas et al. (2018)

identified that eccentric flywheel training and traditional resistance training resulted in similar increases in muscle strength, muscle power, and muscle mass. Vicens-Bordas et al. (2018) addressed some methodological shortcomings associated with the Maroto-Izquerdo et al. (2017) systematic review. The main concern was that of the total number of studies included in Maroto-Izquerdo's systematic review, 67% failed to directly compare eccentric flywheel training (with or without an overload) to traditional resistance training groups and also both randomized and non-randomized controlled trials were included which might have affected their findings (Suchomel et al. 2019). Therefore, further study is required to compare training adaptations from eccentric flywheel overload training to traditional resistance training (Suchomel et al. 2019).

From the literature, most of the exercises used in training regimens involved knee extensions (Greenwood et al. 2007; Onambele et al. 2008; Norrbrand et al. 2008;2010; Maroto-Izquerdo et al. 2017) focusing on one muscle group. With regards to squat strength using a traditional barbell back squat as our measure, our study revealed that both groups (EFOT- 34%; TRT- 50%) showed significant improvements over time. These findings are in contrast to Norrbrand et al. (2011) study which assessed quadriceps muscle use using either a barbell squat or a flywheel squat in 10 strength trained middle-aged men. They concluded that flywheel squat led to greater improvements in quadriceps strength than barbell squat.

Our study revealed a main effect of time for lean tissue and fat mass, indicating that, the EFOT and TRT groups showed similar increases in lean tissue mass and decreases in fat mass over time. The increase in lean tissue mass (2%) is slightly larger than that found in a study conducted by Mueller et al. (2009), who observed (0.6% and 0.3%) increases in both the eccentric and concentric groups. The exercises engaged in were quite different from the ones used in our study, but the study involved an eccentric overload regimen, which was part of the flywheel intervention in our study. Important to note however is that the above study did not involve the flywheel technology. Participants averaged 80.6 years. The intervention took 12 weeks, with participants coming in 2 times a week. Another study conducted by Suarez-Arrones et al. (2018) in football players (16-18years of age) over a 27-week period of 2 sessions per week, revealed that an inertial flywheel eccentric overload protocol resulted in a substantial decrease of whole-body fat mass (3.6%) and an increase in lean mass (0.8%). They indicated however that these improvements had no correlation to performance. The findings from this study are similar to our study in that we also had significant reductions in whole body fat mass and increases in lean body mass after successfully completing the intervention. More specifically, we saw a 7% and 10% decrease in fat mass in the EFOT and TRT groups respectively. In addition, we had 2% increases in lean mass in both groups. It is important to note, however, that this study did not compare eccentric overload flywheel training to traditional resistance training. Due to the novelty of the flywheel system (Julian et al. 2018) much research still needs to be done to compare both training methods; EFOT and TRT to better understand the similarities or differences that exist between the two.

Despite the increase in lean mass observed in our study, similarities were observed over time in muscle thickness (vastus lateralis) for both groups, indicating that there were no improvements. These findings contradict those observed by Norrbrand et al. (2008). They compared a flywheel group with an eccentric overload component to a weight training group for a period of 5 weeks in middle-aged men. Both the flywheel and weight training groups increased significantly in quadriceps muscle volume. We are unsure the reason why we did not see improvements in muscle thickness especially after engaging individuals in a longer intervention program of 16 weeks and observing changes in whole body lean mass. It could be that other muscles increased in size, aside from the vastus lateralis and therefore there was an increase in lean tissue mass at the whole body, especially since other exercises were included in the study.

Overall, both the EFOT and TRT groups showed similar improvements over time, excluding concentric strength and muscle thickness, without any main effects for group or interactions. This would mean that both training methods could be similar in improving isometric, eccentric, 4RM squat, 4RM bench press, 4RM deadlift strength, lean mass, and also reducing fat mass in healthy older adults. These findings are in line with the meta-analysis conducted by Vicens-Bordas et al. (2018), who found similar results indicating that EFOT had no superiority over TRT on improving the aforementioned variables in older adults. However, the findings from the study contradict Maroto-Izquerdo et al. (2017), who indicated that EFOT is a more superior approach to be used. Contrary to our hypothesis, the EFOT group showed no significant differences in improving muscle strength, lean mass, and, reducing fat mass when compared to the TRT group.

5.3 The secondary hypothesis of this study was to identify whether eccentric flywheel overload training will result in greater increases in functional performance (30s sit to stand, incremental shuttle walk test, functional reach test and stair climb power test) than traditional resistance training within a whole-body strength program.

From pre to post-test we saw similar improvements (increases) in 30s sit to stand performance for both the EFOT group (35%) and the TRT group (47%). These findings are similar to those observed by Fernandez-Gonzalo et al. (2014). Their research involved 12 individuals that had experienced stroke in the past 8 years. These individuals were engaged in flywheel leg presses twice a week for a period of 8 weeks, combining concentric and eccentric actions. Results from their study revealed a significant improvement in 30s sit to stand performance and other functional measures not relevant to our study (timed up and go, 6 m walk test). There were; however, some methodological differences in that the Fernandez et al. (2014) study did not compare the EFOT to a TRT group and neither did they involve active healthy older adults.

Our study further showed that over time there were no improvements in incremental shuttle walk performance in both the EFOT and TRT. A few studies have looked at similar functional performance measures; 6 min walk test and 6m fast walk (Raj et al. 2012; Fernandez-Gonzalo et al. 2014; Dias et al. 2015). Results from these studies are in contrast to those observed in our study. Raj et al. (2012) concluded that both eccentrically biased and concentrically biased weight training lead to similar improvements in 6 m fast walk test.
Our study also showed no improvements in functional reach test for both groups over time. The lack of improvements in both the incremental shuttle walk test and the functional reach test could be as a result of the high level of baseline fitness and activity of our participants which may result in a reduction in the likelihood to detect differences. Mueller et al. (2009) in their study observed a similar limitation; however, they used different functional performance measures.

The last functional performance measure included in our study was the up and down stair climb power test. Results from our study indicated that both the EFOT (9%) and TRT (3%) groups showed similar improvements over time. Raj et al. (2012) in their study found contradicting results. After engaging 28 older adults in a 16-week training intervention using either eccentrically biased or concentrically biased weight training, the latter group demonstrated a 5% increase in stair climb and descent performance from before to after intervention. The Raj et al. (2012) study however did not focus on the same exercises that we did in our study and also did not use the same equipment. Their study involved assessment of stair-climb and descent separately. For our study there was no separation between the times for stair climb and descent; the stopwatch was started and stopped when participants ascended and descended. The slight alteration in the conduction of the test may reduce the generalizability of these results.

5.4 Strengths

This study is one of the few studies that compared eccentric flywheel overload training and traditional resistance training and their effect on muscle strength, muscle thickness, body composition, and functional performance in healthy older adults (using compound exercises like squats). Although previous research assessed flywheel training in older adults, very few of these studies focused on "active, healthy and untrained older adults" or involved compound exercises like squats. Our findings in healthy older adults support those observed by Vicens-Bordas et al. (2018), who reported similar findings in their meta-analyses.

Another major strength of the study was that the training involved whole-body exercises, and not just the movement of interest (i.e. squats). In this way, participants were able to benefit from a well-rounded program that would more accurately reflect what is done in practice. As such, as part of a whole-body training program, the addition of flywheel eccentric overload squats can result in similar adaptations as those with the traditional barbell.

5.5 Limitations

A major limitation of the training protocol for EFOT is that the method of inducing eccentric overload is fairly complex and proved difficult for participants to learn. This protocol has not been studied to determine its efficacy and we are unaware if it would be effective in inducing a true eccentric overload. As such, future work should examine different protocols of loading using the flywheel to determine its applicability as a training method.

Another limitation observed involved the sample size generated for the study. Even though this was a pilot study, there is a possibility that the small sample size influenced the outcome of the study i.e. being able to evaluate small differences. Summarily, statistical power was lower.

There is a possibility that any of the findings in this study regarding the adaptations to the squat maneuver and the muscles involved could have been influenced by the remainder of the training program. However, since the training was similar between groups, any influence of the remainder of the training would likely be consistent between groups.

Participants in this study were higher functioning older adults as shown by performance scores in 30s sit to stand and up and down stair climb power tests. Average number of repetitions for the 30s sit to stand test was 19 and 18 for the EFOT and TRT respectively. This average increased after the intervention program to 25 (EFOT) and 27 (TRT). When compared to existing age-related norms (Rikli & Jones, 1999), our participants had better performance for this test. Results of this study cannot be generalized to older adults who have less functional abilities where the functional tests would be more sensitive in detecting differences between training protocols.

5.6 Practical Relevance

Findings from this study would add more evidence to prior research on the effects of EFOT and TRT on muscle strength, muscle thickness, body composition, and functional performance. From a practical standpoint, it can be suggested that both training methods are similarly effective in improving body composition (lean/fat mass) and increasing muscle strength (isometric, eccentric, 4RM squat, deadlift and bench press) and functional performance (30s sit to stand and up and down stair climb power test) in high functioning older adults.

5.7 Future Directions

Future research should be conducted with a larger sample size and recruiting participants with different physical activity levels. In addition to the above, future research should examine different testing methods using flywheel technology and different training protocols to attempt to optimize the training stimulus for older adults.

5.8 Conclusion

The results of this study provide initial evidence that training using a flywheel system of eccentric squat overloading results in similar adaptations as traditional barbell squat training, in the context of a whole program. Eccentric flywheel overload training and traditional resistance training had similar influences on muscle strength (isometric, eccentric, 4RM squat, deadlift and bench press), body composition (lean/fat mass), and functional performance (30s sit to stand and up and down stair climb power test) in healthy older adults.

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APPENDIX A: PARTICIPANT INFORMATION AND CONSENT FORM

A Comparative Study on the Effects of Eccentric Flywheel Overload and Conventional Resistance Training on the Physiological/Functional Performance in Healthy Older Adults:
A RCT Feasibility Study

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Oluwadamilola Odeleye
Masters Student, College of Kinesiology

Emergency Telephone Number:
306-281-8304

Introduction

You are invited to take part in this research study because you have not participated in resistance training in the past 6 months, and are an active, healthy older adult.

Your participation is voluntary and it is up to you to decide whether or not you wish to take part. If you are willing to be a participant in this study you will be required to fill out this form and if at any point during the study you decide to withdraw from participating in this study, you are free to do so at any time and without giving any reasons for your decision.

It is important that you read and understand the following information. Please feel free to ask the primary researcher or research staff any questions that will help you understand the study and what you are expected to do. Before you agree to take part in this study, you may take this information home and discuss it with a family member.

Who is conducting this study?

This study is part of a student researcher's Masters project supervised by Dr. Scotty Butcher, a faculty member in the School of Physical Therapy 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.

Why is the study being done?

This training study (experimental) seeks to identify the effect of an eccentric flywheel overload training; EFOT (muscle lengthening training with a rotating wheel in a machine) using a constant load with longer exposure time at the eccentric phase (muscle lengthening period) on muscle strength/power and functional capacity of older adults (the ability of older adults to function) in comparison with a traditional resistance training - TRT (training that involves free weights). In older adults, there is very little research comparing EFOT with TRT using compound movements (movements that require more than one muscle group e.g. squats), and for this reason the following research questions are highlighted below:

1. Can Eccentric Flywheel Overload Training result in greater increases in isokinetic knee extension strength, squat strength, lean mass; and greater decreases in fat mass than traditional barbell squat training within a whole-body strength program in healthy older adults?

2. Can Eccentric Flywheel Overload Training result in greater increases in functional performance than traditional resistance training within a whole-body strength program in healthy older adults?

The information from this study will help the researchers understand how different loading techniques may be used for testing and training in the future. Furthermore, it is expected that the study outcomes will be useful in terms of strength training and functional performance improvement in older adults.

For this study, a total of 30 untrained, active, healthy older adults (participants) will be recruited from the community and randomized to participate in one of two different strength training programs. In essence, this means that participants can't choose what group they would like to be in as this process would be strictly through random assignment to avoid any selection bias.

Who can participate in the study?

You are eligible to participate in this study if you are healthy, active, age 55 and above, and have not engaged in resistance training for the past 6 months. If you have a significant medical concern (heart disease, lung disease, diabetes, or bone/joint problem) ***that would limit your ability to exercise/strength train or probably worsen by your engagement in exercise***, you are not eligible to participate in this research study.

The testing sessions will be booked within three 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?

Screening/Baseline testing:

Table 1: Study Flow

WEEK	DAY - SESSION	DESCRIPTION	LOCATION
1	**1 Screening**	**Screening Phase 1 (over the phone): health history, cardiovascular risk assessment (ACSM and Get Active Questionnaire)** **Screening phase 2 (in person): vitals (blood pressure and heart rate), hip-waist**	**School of Physical Therapy (Rehabilitation Science)**

		circumference, ultrasound, knee extension tests, and functional tests	
1	**2 DEXA (X-ray machine that assesses total body lean and fat mass)**	**Body composition**	**Williams**
2-3	**3-8 Familiarization**	**Learning the exercises and field tests**	**Synergy**
3	**9 Field tests**	**KBox Power test, Barbell 4 Repetitions of squats with maximum strength**	**Synergy**
4-17	**10-50**	**Training**	**Synergy**
18	**51 Field tests**	**KBox Power test, Barbell 4 Repetitions of squats with maximum strength**	**Synergy**
18	**52 DEXA**	**Body Composition**	**Williams**
18	**53 Lab measures**	**Ultrasound, knee extension machine, functional tests, and hip-waist circumference**	**HSc 3480**

Note: The KBox is a Flywheel device (a rotating wheel) that would be used for testing.

Study Procedures: The study flow is presented in Table 1 above.

Pre-Screening/Screening:

Phase 1 (Pre-Screening): The first stage of the screening procedure will occur over the phone. You will be contacted and information about your health history and any health-related risks you might have will be collected.

Phase 2 (Screening): You will be contacted and you will undergo screening for inclusion (untrained but healthy and active, ages 55 and above) and exclusion (medical concerns- heart disease, lung disease, diabetes or bone/joint problems- for example, previously diagnosed osteoporotic, fragility fracture within the past 2 years, joint arthritis with pain present daily and causing limits to functional activity, presence of joint replacements or presence of an acute injury in the past 6 months) criteria, vitals (blood pressure and heart rate), cardiovascular risk

(American College of Sports Medicine and Get Active questionnaire protocols) and waist and hip circumference measures. If you are found to be at risk of the conditions highlighted above you will be exempted from the study.

Once that is completed, you will be assessed on your muscle strength, muscle thickness and functional capacity using an isokinetic dynamometer, an ultrasound machine and functional tests (functional reach test, 30s sit to stand, stair climb power test and incremental shuttle walk test) respectively.

Body Composition: Lean tissue, fat, and bone mass will be assessed with dual energy X-ray absorptiometry (DEXA) by a nuclear medicine technologist in the RJD Williams Building (221 Cumberland Ave North, Room 108). The DEXA is very similar to a regular X-ray. You will be asked to lie facing up on a padded bed with an x-ray generator below and a detector (an imaging device) above. Once on the table you will be asked to lie flat and still with toes pointing inward for approximately 7 minutes while the arm of the machine passes over your body taking measurements. It is important that you stay as still as possible during the procedure so that the image gotten would be clear and useful. The scan takes about 10 minutes and causes no discomfort whatsoever.

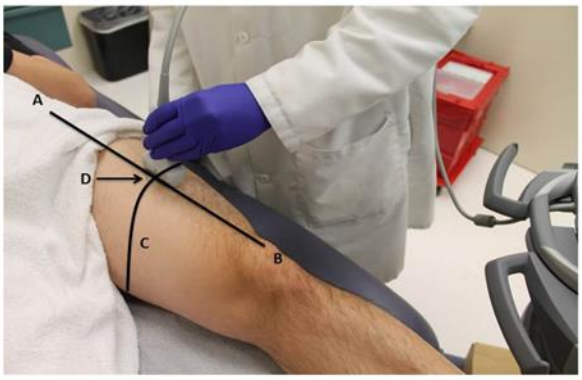
There is a small amount of radiation exposure from the dual energy x-ray absorptiometry scans. This is the equivalent of ~10 µSv. Even if we have to repeat both scans, the radiation dose would be comparable to the amount of background radiation a person receives in one week from naturally occurring sources in Saskatchewan. For reference, a cross-country flight could expose a person to about 30 µSv of radiation. For more information you can visit: http://www.hc-sc.gc.ca/hc-ps/ed-ud/respond/nuclea/measurements-measures-eng.php

Figure 6: Picture showing body composition measurement using a Dual Energy X-ray Absorptiometry scan (whole body). Discovery X-ray Bone Densitometer, manufactured by Hologic Inc

<u>Lab Measures</u>

<u>Quadriceps (muscle front of thigh) Ultrasound:</u> Ultrasound imaging uses sound waves to produce pictures of the inside of the body. It is used to help diagnose the causes of pain, swelling and infection in the body's internal organs and more specifically for this study, it will be used to monitor muscle thickness and cross-sectional area of the quadriceps. Ultrasound is safe, non-invasive, and does not use ionizing radiation. Measurements using the ultrasound will be performed on the right vastus lateralis muscle of the participant. For the quantitative measurement of the muscle thickness, a LOGIQ e BT08 GE Healthcare Scanner (GE Medical Systems, Milwaukee, Wisconsin, USA) with a 12 MHz linear array (38 mm) transducer will be used.

You will be positioned lying face up on an examination table that can be titled or moved, in case the need arises for a change in the lying state. After being positioned properly on the table the radiographer will apply a warm water based gel to the specific part of your body to be studied (i.e. vastus lateralis). The gel ensures that the transducer to be used will have secure contact with the participants' skin and prevent inaccurate reading/transmission of the sound waves. The transducer will be moved back and forth on the part of your body being studied until desired images are gotten. To ascertain the right spot to place the transducer, bony landmarks will be palpated, lines will be drawn and the transducer will be placed in the same spot for both pre and post-tests. This test should take approximately 30 minutes.



A picture showing an ultrasound on the quadriceps Harris-Love, (2016). Retrieved from https://peerj.com/articles/1721/

Isokinetic dynamometry: You will be asked to perform knee straightening exercises on an isokinetic Dynamometer- an instrument that measures your power output (Humac NORM), at 60 degrees per second to assess baseline muscle strength and power. Both the eccentric (muscle lengthening) and concentric (muscle shortening) phases (periods) of the knee extension will be recorded. It is recommended that you wear comfortable exercise clothing. This assessment will be overseen by a Kinesiologist. The best of three trials will be recorded and it should last for about 15 minutes.

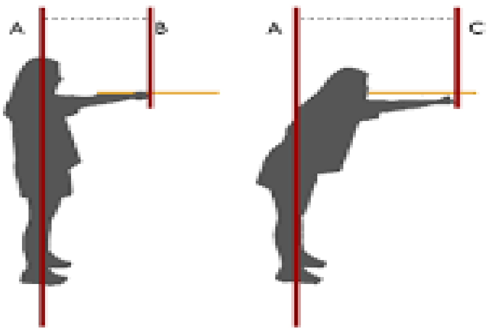
a). A picture showing the process of a knee b). A picture showing a knee extension on extension an Isokinetic dynamometer

Thomson et al. (2018). Retrieved from

https://myhealth.alberta.ca/health/Pages/conditions.aspx?hwid=zm5042&

Functional Tests

Functional Reach Test: A functional reach test is the maximal distance you can reach forward beyond arm's length, while maintaining a fixed base of support (without moving your legs) in the standing position. Functional reach is tested by placing a yardstick or tape measure on the wall, parallel to the floor, at the height of the acromion of your dominant arm. You will be asked to stand with the feet a comfortable distance apart, make a fist, and forward flex the dominant arm to approximately 90 degrees. You will be asked to reach forward as far as possible without taking a step or touching the wall. The distance between the start and end-point is then measured using the head of the metacarpal of the third finger as the reference point.



A Picture showing a Functional Reach Test. Retrieved from http://walnutmedical.in/functional-reach-test-frt-and-modified-frt-mfrt/

Up and Down Stair climb Power Test: You will be asked to ascend a flight of 10 stairs as quickly as you can. The time in which it will take you to get to the top will be recorded. You are permitted to hold on to the railings while ascending if support is required. At all times there will be a researcher/trainer to assist you in case you feel light-headed or lose balance.

30 second sit to stand: For this test, you will start in a seated position. When the researcher cues you, you will stand up and sit down as many times as possible within the space of 30 seconds, with the arms crossed and placed on each shoulder.

Incremental shuttle walk test: During this test you will be asked to walk between two cones spaced 10 metres apart. The activity will begin as soon as you start walking slowly; this pace is set by a beep. You will walk around the 10-metre course aiming to turn around a cone at the first beep, and around the second cone at the next beep. The beeps will very gradually get faster, which means you will begin to walk at a quicker pace, getting faster and faster until the pace can't be kept up, or until you run out of breath or become too tired to continue.

The functional tests will last for 30 minutes.

The total time for the ultrasound, isokinetic dynamometry, functional performance tests and the questionnaires should be approximately 2 hours.

Familiarization

Learning the movements and ramp up intensity: The familiarization and ramp up sessions you will be involved in will take place for 3 weeks and you will be required to come in 2 times each week for 1 hour each time with at least 48-hr recovery between training sessions. The emphasis for this period will be for you to learn the required techniques to accurately and conveniently carry out exercise routines on your own during the 16-week training program.

P.S. training progression for this study would be a gradual build-up of your rate of perceived exertion (RPE). This would prevent muscle injury and further delay the onset of muscle soreness. You will be properly educated on Delayed Onset of Muscle Soreness (DOMS) during the familiarization sessions and informed that you might likely feel pain/soreness which would go away after a couple of days.

Standardized Warm up: You will be guided through a series of low intensity exercises (for example, air squats and flexibility exercises) by trained coaches, and this will last for about 10-15 minutes.

Accommodation to Protocols: Following the warm up, you will then be taught certain movements required for the training and develop accommodation to the protocols. Furthermore, you will also be familiarized with the equipment that will be used during the testing. You will learn how to squat, deadlift, press, and row and will also learn how to use the flywheel.

Field Tests

KBox Power test: After completing the standardized warm-up protocol, using the specialized flywheel device (a rotating wheel in a machine), you will be shown how to perform the KBox power test protocol (i.e. squats on a flywheel device).

A Picture showing the Kbox power test

Traditional Barbell Back Squat 4RM: After completing the standardized warm-up, you will perform several back squats and will continue to increase the load on the barbell gradually until you can complete 4 full squat repetitions only. A minimum of 3 minutes rest will be provided between maximal attempts to minimize fatigue. You will be instructed to maintain a consistent squat depth (either terminating eccentric phase when top of the thigh is parallel to floor or below) for each squat repetition.

A picture showing a barbell backsquat

<u>Random Allocation Process</u>

After testing, you will receive a sequentially numbered, opaque, sealed and stapled envelope, which will contain on the inside, the particular group (eccentric flywheel group or the barbell training group) you have been assigned to.

<u>Training Programs</u>

<u>General:</u> Both groups will complete 13 weeks of training 3 times per week for duration of 1 hour for each time you come in. No matter which group you are assigned to, you will complete the same whole-body strength training program with an emphasis on compound lifts (squats, deadlifts, presses, rows). Squats will be trained twice a week and deadlifts once a week in both groups. For the main compound lifts, 4 sets of 6 repetitions will be performed by both groups. The only differences between group training will be the implement used (Flywheel or Barbell) for squats and deadlifts.

<u>Eccentric Flywheel Overload Training group:</u> For the flywheel group, squats and deadlifts will be performed using the kBox flywheel ergometer. The flywheel group will start training using about 80% effort and will be increased to 10/10 effort over the subsequent weeks. The duration for each training is 1 hour.

Traditional Resistance Training group: For the barbell group, squats and deadlifts will be performed using a barbell (straight, safety squat, or trap bar depending on your mobility) for 4 sets of 6 repetitions. The weight will be progressed slowly each session as you are able. The duration for each training session is 1 hour.

Post-training Testing

After the 16 weeks of familiarization and training, you will be asked to repeat the DEXA, ultrasound, isokinetic strength tests, field tests, and functional tests as outlined above.

The first day of post testing will be for one hour and this would involve the Kbox power test and the 4 repetition maximum using the barbell.

The second day will take approximately 30 minutes and you will be coming in to get your body composition assessed.

The final day of post testing will take 2 hours and this will include functional tests, ultrasound, isokinetic dynamometry and questionnaires.

At any point during the testing session, the researchers may take videos 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 videos and/or pictures taken of you at the end of this consent form. If you choose not to have videos and/or pictures taken, you are still able to participate in this research study.

What are my responsibilities?

As a study participant you will be expected to:

a. Follow the directions of the Principal Investigator
b. Report any changes to your health to the Principal Investigator
c. Complete a weekly recall diary on muscle soreness

What are the benefits of participating in this study?

Once you this study is completed, you may see improvements in your strength and functional performance, but these results aren't guaranteed. It is hoped that the results from this study will allow rehabilitation, strength and conditioning, biomechanics and ergonomic professionals to clearly understand and implement flywheel eccentric overload training methods, using compound movements (movements that require more than one muscle group e.g. squats) to promote strength/power in older adults. In addition, it is expected that the information acquired concerning improvements in the functional performance of older adults through eccentric overload will be used to maintain/increase the functional state of older adults worldwide.

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, and also radiation from the DEXA scan. These risks include:

- *Acute muscle and/or joint injury will likely occur and it can be compared to the discomfort you would feel when starting a new training program at the gym*
- *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.

There is a small amount of radiation exposure from the dual energy x-ray absorptiometry scans. This is the equivalent of ~10 µSv. Even if we have to repeat both scans, the radiation dose would be comparable to the amount of background radiation a person receives in one week from naturally occurring sources in Saskatchewan. For reference, a cross-country flight could expose a person to about 30 µSv of radiation. For more information you can visit: http://www.hc-sc.gc.ca/hc-ps/ed-ud/respond/nuclea/measurements-measures-eng.php.

What happens if I decide to withdraw?

Your participation in this research is voluntary and you may decide to withdraw at any point if you feel uncomfortable or unable to continue. Your future academic status and/or relationships with the Strength and Conditioning facility or the University of Saskatchewan will not be affected.

If after consideration during the course of the study you decide to withdraw, all data collected about you during your enrolment will be retained for analysis.

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 I be informed of the results of the study?

The results of the study will be provided to you after the study is complete. You will be sent your own personal results document via email. The email will contain your 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, neither will you 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.

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 and medical 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. Nevertheless, 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. In addition to the above, you would be assigned a number unique to you to reduce the risk of your confidentiality being breeched.

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*.

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

Participant Consent Form

Study Title: A Comparative Study on the Effects of Eccentric Flywheel Overload and Conventional Resistance Training on the Physiological/Functional Performance in Older Adults

- 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:

Printed name of participant:	Signature	Date
Printed name of person obtaining consent:	Signature	Date

APPENDIX B: INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (IPAQ)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

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

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

PART 1: JOB-RELATED PHYSICAL ACTIVITY

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

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

☐ Yes

☐ No → ***Skip to PART 2: TRANSPORTATION***

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

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

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

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

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

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

_____ **days per week**

☐ No moderate job-related physical activity → ***Skip to question 6***

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

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

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

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

_____ **days per week**

☐ No job-related walking ➡ ***Skip to PART 2: TRANSPORTATION***

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

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

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

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

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

_____ **days per week**

☐ No traveling in a motor vehicle ➡ ***Skip to question 10***

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

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

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

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

_____ **days per week**

☐ No bicycling from place to place ➡ ***Skip to question 12***

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

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

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

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

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

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

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

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

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

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

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

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

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

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

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

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

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

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

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

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

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

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

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

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

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

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

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

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

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

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

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

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

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

PART 5: TIME SPENT SITTING

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

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

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

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

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

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

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

APPENDIX C: GET ACTIVE QUESTIONNAIRE (GAQ)

CSEP | SCPE

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 before you become more physically active. If you are unsure about any question, answer **YES**.

YES	NO	
		1 Have you experienced **ANY** 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?

NO to all questions: go to Page 2 – ASSESS YOUR CURRENT PHYSICAL ACTIVITY

YES to any question: go to Reference Document – ADVICE ON WHAT TO DO IF YOU HAVE A YES RESPONSE

APPENDIX D: HUMAC NORM DATA COLLECTION FORM

Participant____

Humac shaft height and angle		
Chair runner position	[L]	[R]
Chair angle and color		
Chair backing lever and wheel	[90]	[17]
Pad used?	[Neck]	[Seat]

Contractions	Trial 1 (Max)	Trial 2 (Max)	Trial 3 (Max)	Trial 4	Trial 5	Trial 6
Isometric						
Concentric						
Eccentric						

APPENDIX E: ULTRASOUND DATA COLLECTION FORM

Ultrasound Measurements

Participant	Vastus lateralis length Landmarks: ASIS, top of patella	65% length of Vatus Lateralis (from ASIS)	Distance from lateral side to 65% mark	Mid point between lateral and 65%	Probe Placement
0001					

Preferred Leg Placement: Both legs extended or contralateral

Position of probe for each participant

Instruments Used

1. Ultrasound 4. Tape rule

2. Probe 5. Marker or pencil

3. Gel

APPENDIX F: 30S SIT TO STAND

30 second Chair Stand Test

(Rikli, Jones 1999)

Chair height: 17” (43 cm), placed against wall for stability

Starting position: sitting in the middle of the chair, back straight, arms crossed over chest, feet flat on floor.

1. Take resting vital signs.
2. Demonstrate the movement, first slowly, then quickly.
3. Have the patient/client practice one or two repetitions to ensure proper form, and adequate balance
4. On the signal “go” the patient/client rises to a full stand, then returns to a fully seated position, as many times as possible in 30 seconds.
5. If a person is more than half way up at the end of the 30 seconds, count it as a full stand.
6. One trial.
7. Take post exercise vital signs.
8. Document any modifications (chair height, assistance needed)

Range of scores is between the 25% and 75% percentiles		
Age	**Men: number of stands**	**Women: number of stands**
60 – 64	14 – 19	12 – 17
65 – 79	12 – 18	11 – 16
70 – 74	12 – 17	10 -15
75 – 79	11 – 17	10 – 15
80 – 84	10 – 15	9 – 14
85 – 89	8 – 14	8 – 13

90 – 95	7 – 12	4 – 11

Scores less than 8 (unassisted) stands were associated with lower levels of functional ability

Population:

- community residing older adults ages 60-94
- n = 7,183 5,048 women, 2,135 men
- years education: 14.5
- chronic conditions: 1.7
- medications: 1.6
- performed moderate exercise $\geq$3 times/week: 65%

Exclusion criteria:

- advised not to exercise by physician
- CHF, joint pain, chest pain, dizziness, angina during exercise
- BP > 160/100

Rikli RE, Jones CJ (1999). Functional fitness normative scores for community residing older adults ages 60-94. Journal of Aging and Physical Activity, 7, 160-179.

APPENDIX G: INCREMENTAL SHUTTLE WALK FORM

Shuttle Walk Test Recording Form

Unit:

Designation:

Date:

ID:

First name:

Last name:

D.O.B. (dd/mm/yyyy)

Diagnosis:

Medication taken today	Dose	How many hours prior to testing?

Supplemental oxygen: yes/no
Flow rate:
Device:
Method carried:

Walking aid: yes/ no (specify)

Level:		1	2	3	4	5	6	7	8	9	10	11	12
ISWT	1												
	2												

		ISWT1	ISWT2			ESWT1	ESWT2
				Date/ Time:			
Date/ Time:				Speed/ level:			
Start	Dyspnoea			Start	Dyspnoea		
	HR				HR		
	SpO_2				SpO_2		
Distance (m):				Time (seconds):			
End	Dyspnoea			End	Dyspnoea		
	Exertion				Exertion		
	HR				HR		
	SpO_2				SpO_2		
Recovery	Dyspnoea			Recovery	Dyspnoea		
	Exertion				Exertion		
	HR				HR		
	SpO_2				SpO_2		
Reason for termination				Reason for termination:			

ESWT calculation:

Comments:

Print: Signature:

APPENDIX H: FUNCTIONAL REACH FORM

General Information: The Functional Reach test can be administered while the patient is standing (Functional Reach) or sitting (Modified Functional Reach).

Equipment Needed:

1. A yardstick and duct tape will be needed for assessment

2. The yardstick should be affixed to the wall at the level of the participant's acromion

Functional Reach (standing instructions):

- The patient is instructed to next to, but not touching, a wall and position the arm that is closer to the wall at 90 degrees of shoulder flexion with a closed fist.
- The assessor records the starting position at the 3rd metacarpal head on the yardstick.
- Instruct the patient to "Reach as far as you can forward without taking a step."
- The location of the 3rd metacarpal is recorded.
- Scores are determined by assessing the difference between the start and end position is the reach distance, usually measured in inches.
- Three trials are done and the average of the last two is noted.

Functional Reach Test and Modified Functional Reach Score Sheet

Name:____

Instructions:

Instruct the patient to "Reach as far as you can forward without taking a step"

Score Sheet:

Date	Trial One (Practice)	Trial Two	Trial Three	**Total (average of trial 2 and 3 only)**

APPENDIX I: UP AND DOWN STAIR CLIMB POWER FORM

Stair climb Power Test

“For this test, do the best you can by going as fast as you can but don’t push yourself to a point of overexertion or beyond what you think is safe for you.

- Start with both feet on the bottom landing.
- On start, go to the top of the stairs as fast but as safe as you can, turn around and return back down and stop with both feet back on the ground landing.
- Use the rail only if needed.
- Get ready and START”.
-

Participant:____

Instructions:

Score Sheet:

Date	Trial One (Practice)	Trial Two	Trial Three	**Total (average of trial 2 and 3 only)**

APPENDIX J: SCREENING QUESTIONS OVER THE PHONE

Screening: Phase 1 (Over the phone)

Questions

1. How old are you? (Individuals had to be 55 and above)
2. How physically active are you? Rank yourself (low, medium or high?)
    a. What activities do you engage in?
    b. How many times in a week?
    c. How long are these activities?
3. Health History or Concerns? Yes/No?
    a. Yes? What are they?
    b. How long ago were you diagnosed?
    c. Are you taking any medication for this?
    d. Would this condition affect your participation in this study?