Velocity of movement during ankle strength and power training with elastic resistance bands in older patients attending a day hospital rehabilitation program

by

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ABSTRACT

The purpose was to determine the velocity during strength and power training, with elastic resistance bands, in older adults. Nine older patients, who attended the day hospital rehabilitation program at Riverview Health Centre, were trained for power and strength of the ankle muscles using elastic resistance bands for 4 to 6 weeks. Training sessions were filmed to assess the velocity of training using Proanalyst software. Power training occurred at faster peak velocities as compared to strength training ($p<0.001$) for both muscle groups, however there were significant differences for average velocity only during training of plantar flexors ($p<0.001$). There was no significant difference between strength and power training in terms of within individual variability. However, a wide variability was observed between subjects in velocities they trained at and overlap was found between velocities for strength and power training. Hence, researchers should monitor velocity during different types of training in older adults.

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DEDICATION

I would like to dedicate this work to my daddy, who I am very sure, is all smiles to see his daughter succeed in her endeavors. He has always encouraged me and created this appreciation for education and has taught me how to live a good life. Your blessings have helped me cross this ocean, daddy!

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Introduction

The World Health Organization (WHO) describes aging as “a privilege and a societal achievement” (World Health Organization, 2009). Almost one Canadian out of seven (13.9%) is 65 years of age or older (Statistics Canada, 2009). They form 12% of the current population. Since 1920, the life expectancy has increased by an average of seven years for men and 13 years for women. In the coming decades, older adults will comprise a larger share of the Canadian population, growing from 3.9 million people in 2001 to an estimated 6.9 million by 2021 and to 9.2 million by 2041 (Health Canada, 2005). The population of older adults in Manitoba is estimated to increase from 13.5% in 2000 to 18.8% in 2021 (Health Canada, 2005).

Life expectancy in Canada has increased due to improvements in public and population health (Health Canada, 2005). However, in older adults, this increased life expectancy comes with increased incidence of chronic disease, and a decline in physical function (Nikolova et al, 2011) and cognition (Nikolova et al, 2009). These, in turn, cause a decrease in the ability to perform activities of daily living such as climbing stairs, getting up from a chair and doing basic household chores (Nikolova et al, 2011), and the final outcomes are disability, dependence and increased morbidity and mortality for older adults (Jitapunkul et al, 2003). In some cases, functional limitations are due to underlying disease, but in other cases, they are simply caused by age-related changes that occur in the body, which includes neuromuscular function.

1. Age related changes in the neuromuscular system

1.1. Changes in muscle mass

With aging, the limb muscles of older adults have more fat and connective tissue (Delmonico et al, 2009), and there is a gradual decrease in the size and volume of the muscle (Goodpaster et al, 2006). In the study on cadavers by Lexell et al (1988), it was shown that there is a reduction in the number of muscle fibers with age. Type 2 fibers are smaller in size with aging (Lexell, 1995; Lee et al, 2006; Brunner et al, 2007). There is conflicting evidence about the effect of aging on type 1 fiber; whether the proportion remains unchanged (Lexell, 1995) or increases (Lee et al, 2006; Jones et al, 2009) or decreases (Larsson et al, 1986) is still uncertain. Also, whether the size of type 1 fibers remains unchanged (Lexell, 1995; Lee et al, 2006) or decreases (Larrson et al, 1986; D'Antona et al, 2003) is not clear. However, it has also been found that the aging in muscle could be associated with fast-to-slow fiber transformation (Gannon et al, 2009).

1.2. Changes in the contractile properties of the muscle

The changes in fiber composition in older adults affect the ability to generate force. There is a reduction in the forces generated by the muscles with aging (Lowe et al, 2002; Baudry et al, 2007; Ochala et al, 2007; Yamauchi et al, 2009). Kirkendall and Garrett (1998) in their review noted that type 1 fibers have low force output and a slow maximum velocity of shortening, while type 2 fibers have higher force output and faster velocities. There is prolongation in the twitch contraction and relaxation times as one ages (Vandervoort and McComas, 1986; Dalton et al, 2009; Jones et al, 2009; Dalton and

Harwood, 2010). Fascicle length (Narici et al, 2003; Kubo et al, 2003) and pennation angle (Narici et al, 2003) reduce with aging. However, the ratio of the fascicle length to pennation angle does not change with aging (Morse et al, 2005).

1.3. Changes in the motor unit

There is an increase in the size of the motor units with aging (Kirkendall and Garrett, 1998). In this review, it was postulated that, as a protective mechanism against loss of fibers with aging, collaterals from the type 1 motor neurons expand to the nearby type 2 fibers that are denervated due to aging. Hence, the type 1 motor units increase in size at the expense of the type 2 units. The outcome is a weaker and slower muscle, due to loss of type 2 fibers and increased innervation by type 1 motor neurons respectively. The study by Akataki et al (2002) found that there is altered motor unit activation with aging, with type 1 motor units having a major role to play as compared to type 2 motor units. This high proportion of the slow motor units with aging causes decreased average firing rates with aging as compared to younger adults (Dalton et al, 2009; Dalton and Harwood, 2010). Recovery of the motor unit is also impaired in older adults (Dalton and Harwood, 2010).

1.4. Changes in strength with aging

Aging causes a decrease in the number of spinal motor neurons due to many factors like increased oxidation of the cell, increased levels of cytokines and apoptosis (Aagaard et al, 2010). This in turn leads to denervation of the muscle fibers with an eventual decrease in muscle size and volume. This could probably be the main cause for a decrease in muscle strength with aging (Macaluso and De Vito, 2004; Delmonico et al, 2009). Strength loss accelerates after 65 to 70 years of age and lower limb strength declines at a faster rate as compared to upper limb strength (Chodzko-Zajko et al, 2009). With increasing age, there is a reduction in activities involving the lower limb like walking and stair climbing and this in turn could be the cause for reduced lower limb muscle mass (Granacher et al, 2008) and thus lower limb muscle strength. A change in the pattern of activities with aging, with older adults using more of upper limbs than lower limbs, could also explain this asymmetric muscle strength loss. In the study by Ferrreira et al (2009), the older subjects were asked to maintain a daily activity log record to see which activities were frequently performed in order to note their preference to use upper and lower extremities. It was found that, as compared to younger subjects, they indulged in those activities that involved upper limbs like cooking, sweeping, dusting, shaving, washing windows and cleaning trees, more than those activities that involved lower limbs like walking, cycling and going up stairs.

Decreased strength has functional implications for older adults (Reid and Naumova, 2008) like impaired balance (weaker muscles unable to control sudden changes in movement and maintain postural stability) (Hyatt et al, 1990; Campbell et al, 1997; Onambele et al, 2006; Orr et al, 2008) and increased incidence of falls (Panel on fall prevention, 2001; Lockhart et al, 2005; Menz et al, 2006), increased disability (Roth et al, 2000), increased difficulty to perform the activities of daily living (Puthoff and Nielsen, 2007), and decreased gait speed and walking distance (Krebs et al, 1998; Marsh et al, 2006; Puthoff et al, 2008). Reduced strength also complicates the execution of a task (Tideiksaar, 2002). However, some studies have found that decreased strength does not affect function (Ferucci et al, 1997; Arampatzis et al, 2008). Muscle power, which emphasizes high velocity movement, has been shown to influence function more than strength in older adults (McGibbon and Krebs, 1999; Foldvari et al, 2000; Bean et al, 2002; Skelton et al, 2002; Paterson et al, 2007; Perry et al, 2007; Katula et al, 2008).

1.5. Changes in power with aging

Power is defined as the product of force and velocity. It is given by the following formula:

$$\text{Power} = \frac{\text{Force } \times \text{Displacement}}{\text{Time}}$$

Thus the product of the force and velocity at which muscle shortens or lengthens controls the power production of the muscle (Brooks et al, 2005). Power is influenced by both neural and muscular factors. The neural factors influencing power output are the factors that influence force output (frequency of firing, the number and size of motor units), and the factors influencing the velocity (the type of muscle fiber). The muscle-related factors that affect power output are the length of muscle fiber and position of the fiber length relative to the optimal length - tension relationship. Thus, power output depends on two relationships: length-tension relationship and force-velocity relationship (Brooks et al, 2005; Lieber, 2002; Gardiner, 2001).

1.5.1. Length-tension relationship

It is also known as the force length relationship. Muscles generate maximum force when they are close to their ideal length (often the resting length) at a particular point in the range of motion. For example, the maximum torque produced by the ankle plantar flexors is in dorsiflexion positions (Winegard et al, 1996; Simoneau et al, 2007) or almost full dorsiflexion of the ankle (Sale et al, 1982), while that for the ankle dorsiflexors is a neutral position of ankle joint (Simoneau et al, 2007) or few degrees of plantar flexion (McNeil et al, 2007).

1.5.2. Force-velocity relationship

The velocity with which the muscle contracts also affects, in a hyperbolic fashion, how much force the muscle can produce. The velocity of muscle contraction depends on the internal and external forces that resist the movement. Low velocity movements tend to take place when the muscular forces are higher. High velocity movements occur when the force produced by the muscle is low. Since power is equal to force times velocity, the muscle generates no power in two situations; before the start of movement and after the movement has ended (due to zero velocity) or maximal velocity (due to zero force, when momentum takes over) (Lieber, 2002).

1.5.3. Age-related changes in specific muscle groups of the lower limb

Power decreases with age because of the changes that occur in the neuromuscular system with age like selective atrophy of type 2 muscle fibres (Lexell et al, 1988), shorter muscle fascicles (Narici et al, 2003; Kubo et al, 2003), and impaired recovery of motor units (Dalton and Harwood, 2010). Cross sectional studies have shown that age-related decline in muscle power accelerates with age (Boussuge et al, 2006; Marsh et al, 2006; McNeil et al, 2007; Samuel and Rowe, 2009). Also, past the age of 70, muscle power loss occurs at an accelerated rate of 30% per decade from this age onwards (Cayley, 2008), and it declines by 3-4% per year - almost double the rate at which muscle strength wanes (Young and Skelton, 1994; Ashe et al, 2008). This decline is greater in the lower limb muscles as compared to the upper limb muscles (Candow and Chilibeck, 2005). The three important joints of the lower limb kinematic chain are the hip, the knee and the ankle. Hip strength and velocity decline with age (Dean et al, 2004; Samuel and Rowe, 2009). In the study by Lanza et al (2003), on older adults, it was found that leg extension power declined with age.

1.6. Changes in the ankle joint with aging

The ankle joint plays an important role during foot clearance in the gait cycle (Brooks et al, 2005). The decline in ankle strength after the age of 60 years, occurs at an approximate rate of 1.3 % per year (Vandervoort et al, 1992). In the longitudinal study by Winegard et al (1996), in a cohort of healthy older adults (mean age 84 years), it was found that plantar flexor strength decreased 2.1% per year in older women and 2.5% per year in older men. The loss was less in the dorsiflexor muscles, with the strength reduction being 0.3% per year in older women, and 0.8% per year in older men.

1.7. Functional implications due to changes in the ankle joint with aging

Functional mobility depends on ankle muscle strength (Liu et al, 2007) and power (Suzuki et al, 2001) in older adults and poor ankle muscle strength complicates the execution of a step and older people find it difficult to adjust their centre of gravity in line with base of support rapidly enough to prevent a fall (Tideiksaar, 2002). Increased plantar flexor power increases gait speed and decreases the energy expenditure (Norris et al, 2007). Decreases in the strength of ankle dorsiflexors (Kemoun et al, 2002) and ankle plantar flexors (Menz et al, 2006; Ribeiro et al, 2009) have been shown to be more predictive of falls. Ankle plantar flexor strength is associated with activities like stooping, crouching and kneeling in older adults (Hernandez et al, 2010).

2. Resistance Training

Resistance training can be used to slow down age-related changes in older adults (Porter et al, 1995; Roth et al, 2000; Roubenoff, 2003; Kamel, 2003; Taaffe, 2006; Zacker, 2006; Hautier and Bonnefoy, 2007; Jones et al, 2009). The American College of Sports Medicine (ACSM) guidelines for exercise in older adults (2009) outlined the following favorable responses to resistance training for older adults: increased muscle strength, increased muscle power, improved muscle quality by hypertrophy of type 2 muscle fibers, increased bone mineral density, increased lipid oxidation, increased High Density Lipoprotein (HDL) levels, decreased Low Density Lipoprotein (LDL) levels, and a reduction in triglyceride levels. There are two main types of resistance training programs that have been used in older adults: strength training and power training.

2.1. Types of Resistance Training

2.1.1. Strength Training

Strength training is performing resistance exercise in a slow and controlled manner, with heavy loads. Strength training has been beneficial to older adults (Aagaard et al, 2010) in many ways. Muscle strength and muscle mass have been shown to increase after strength training in older adults (Judge et al, 1994; Skelton et al, 1995; Damush et al, 1999; Connelly and Vandervoort, 2000; Rogers et al, 2002; Latham et al, 2003; Yamauchi et al, 2005; Simoneau et al, 2006; Henwood et al, 2008; Parente et al, 2008; Jones et al, 2009; Liu and Latham, 2009). Other positive effects of strength training in older adults are increases in type 2 fibre cross sectional area (Aniansson et al, 1984; Charette et al, 1991; Parente et al, 2008), reduced fat mass and increased fat free mass (Colado and Triplett, 2008; Henwood et al, 2008), improved cognition (Baum et al, 2003), improved physical function (Rogers et al, 2002; Hruda et al, 2003; Nelson et al, 2004), and a decrease in the risk for falls (Liu-Ambrose et al, 2004; Liu et al, 2007). Nonetheless, some studies have shown that strength training does not influence function (Topp et al, 1993; McMurdo and Johnstone, 1995; Damush and Damush, 1999; Capodaglio et al, 2002; de Vreede et al, 2005; Hanson et al, 2009) and power training was found to be more effective in improving function (Miszko et al, 2003; Stengel et al, 2005; Capodaglio et al, 2005; Bottaro et al, 2007).

2.1.2. Power Training

Power training is performing the concentric phase of exercise “as fast as possible”- it has been performed using both heavier and lower loads. Positive effects of power training have been demonstrated in older adults, like an increase in voluntary activation of the agonists, a significant reduction in antagonist co-activation (Hakkinen et al, 1996; Laroche et al, 2008), less bone loss in post menopausal women as compared to strength training (Stengel et al, 2005), increased muscle endurance (Henwood et al, 2008), and improved balance (Orr et al, 2006).

The muscle groups studied in power training research (see Table 1) include knee muscles (Izquierdo et al, 2001; Fielding et al, 2002; Hruda et al, 2003; Sayers et al, 2003; Bean et al, 2004; Petrella et al, 2007; Reid and Callahan, 2008; Sayers and Gibson, 2010), knee and ankle muscles (Hakkinen et al, 2000; Earles et al, 2001; Signorile et al, 2002), upper and lower extremities (Miszko et al, 2003; de Vos et al, 2005; Stengel et al, 2005; Bottaro et al, 2007; Orr et al, 2006; Henwood et al, 2008; Katula et al, 2008; Iwamoto et al, 2008; Marsh et al, 2009), and ankle muscles (Webber and Porter, 2010).

Seven studies were exclusively conducted on older women (Hakkinen et al, 2001b; Fielding et al, 2002; Signorile et al, 2002; Sayers et al, 2003; Bean et al, 2004; Stengel et al, 2005; Webber and Porter, 2010). Two studies were conducted exclusively on older men (Izquierdo et al, 2001; Bottaro et al, 2007). The duration of power training ranged from 10 weeks to 1 year.

The measurement tools used to note changes, if any, due to power training were functional tests (Earles et al, 2001; Miszko et al, 2003; Hruda et al, 2003; Sayers et al, 2003; Bean et al, 2004; Bottaro et al, 2007; Henwood et al, 2008; Iwamoto et al, 2008; Marsh et al, 2009), leg press machine (Hakkinen et al, 2000; Izquierdo et al, 2001; Earles et al, 2001; Fielding et al, 2002; Bean et al, 2004; Bottaro et al, 2007; Henwood et al, 2008; Katula et al, 2008; Marsh et al, 2009; Sayers and Gibson, 2010), electromyography (EMG) (Hakkinen et al, 2000; Petrella et al, 2007), dual energy X-ray absorptiometry (DEXA) (Stengel et al, 2005; Petrella et al, 2007; Reid and Callahan, 2008; Marsh et al, 2009), balance system (Orr et al, 2006), bioelectric impedance (Orr et al, 2006), Keiser pneumatic equipment (de Vos et al, 2005; Orr et al, 2006) and dynamometers (Hakkinen et al, 2001; Izquierdo et al, 2001; Signorile et al, 2002; Webber and Porter, 2010).

Table 1. Summary of studies on power training in older adults

Study	Nature of subjects	Type of training	Length of training	Measurements	Findings
Bean and Herman 2004	10 W, 11 CON (70 + MI)	Functional resistance training with weighted vests	12 wks, 3 times a week, 30 mins/ session, 3 sets of 10 reps	Leg press, B/L leg press muscle power, functional testing	12% to 35% ↑ in leg power, 75% to 90% ↑in 1 RM, ↑ chair stands, SPPB scores; ↔ CON
Bottaro and Machado 2007	11 PT, 9 ST - inactive older men (60-76 years)	Horizontal leg press, KE, KF, chest press, seated row, EE, EF. ST – slow, controlled ; PT – as fast as possible	10 wks, 2 days per week- 3 sets of 8 to 10 reps, ↑ intensity over sessions.	1 RM leg, bench press for strength, leg press, chest press for power, Rikli and Jones functional fitness tests	↑strength and power in respective groups, ↑function in power group
de Vos et al (2005 and 2008)	112 independent community dwelling older adults (65-70 years)	Training group: Resistance training for strength, power and muscle endurance using Keiser pneumatic resistance equipment Control group: No active treatment	12 weeks, 2 days a week, 2 sets of 8 reps	1 RM strength, FFM, force at peak power, velocity at peak power, peak power, muscle endurance	↑ Average peak power; ↑ Average strength and muscle endurance in training groups. ↑ Peak muscle power in all exercise groups. ↑ Strength in all groups
Earles and Judge 2001	Independent community living older adults (70+)	Exercise group (n=18): Power training of hip, knee extensors	12 weeks, 3 days a week, 3 sets of 10 reps	Pneumatic leg press, SPPB, balance, chair rise, 6-min walk test, 8- foot walk, single	↑ Maximum leg press power by 22%. Strength ↔ between groups. SPPB score ↑ only in

		and plantar flexors Control group (n=22): Walking		leg stance	power group
Fielding and Le Brasseur 2002	30 W (70+)	B/L LP and individual KE, performed at high (HV) and low velocity (LV)	16 weeks, three times a week – 3 sets of 8 reps	LP and KE 1 RM and peak power	↑ LP 1 RM 35% and 33% and KE ↑1 RM 45% and 41% in HV and LV groups; 75% ↑ in peak power in LP and KE. For LP, HV >LV for peak power; ↔KE
Hakkinen et al 1998, 2000, 2001a	Older men (n=11)-69-75 years; older women (n=10)-64-70 years; 1 month control period with the same subjects	B/L leg press, KE exercises, bench press, chest press, lateral pull down, shoulder press; abdominal crunch, rotary torso, TE, standing leg curl, hip exercises. First 8 weeks: load at 50-70% of 1 RM-3 to 4 sets, 10 -15 reps/ set Last 8 weeks: load up to 80% of 1RM	7 months, 1st month-control period; next 6 months-intervention period, 2 days / week	HE, KF, KE, ADF force output using isokinetic dynamometer, dynamic force output using force platform, EMG of thigh muscles, CSA using ultrasonic scanner, muscle biopsies	↑Muscle cross sectional area of both slow and fast fibers in KE of older women, ↔ circulating serum hormones,↑ strength
Hakkinen and Pakarinen 2001 b	10 healthy older women (61-67 years)	B/L leg press, KE on isokinetic dynamometer, bench press, lateral and triceps pull down, sit up	25 weeks, 4 weeks-control period; 21 weeks-exercise period-2 days/week	EMG, 1 RM strength, muscle CSA, muscle fiber proportion, serum hormonal levels, RFP	↑ strength, ↑ RFP, ↑ CSA, ↑ mean fiber areas of type 1 and type 2 fibers, levels of free testosterone related to gains in CSA, acute ↑ in

		exercise, upper limb extensor exercises, leg abductor-adductor exercises; loads ↑ from 40% RM to 80% RM over 21 weeks			GH
Henwood and Taaffe 2008	HV (23:11 M, 12 W), ST (22: 10 M, 12 W), CON (22:10 M, 12 W)	Chest press, supported row, biceps curl, leg press, prone leg curl, and leg extension	24 weeks, two times a week, 1 hour per session-3 sets of 8 reps	1 RM, leg press, chest press, muscle power, movement velocity, BMD, body composition, functional tests, lifestyle questionnaire	↑ Lean mass, ↓fat mass, ↑ muscle endurance and strength in both training groups, ↑ chest press peak power in HV group. ↓Work performed in HV group
Hruda and Hicks 2003	18 M+W (76-94 years), 7 controls (75-87 years)	Body weight and bands used for seated exercises-gradual ↑velocity of movement	10 weeks, 1 hour per session, 3 times per week	Isokinetic KE and strength, 8 feet TUG, 30 s chair stands, 6 m walk test	25% ↑ KE peak torque, 60% ↑ KE average power, 31% ↑ 8-ft-up-and-go timed test, 66% ↑30-s chair stand test and 33% ↑ 6-m walk test; ↔ CON
Iwamoto and Suzuki 2008	68 M+W (66-88 years) randomized to 2 groups	Calisthenics, tandem standing, tandem gait, unipedal standing, muscle power training-chair rise and stepping	5 months, 30 mins per session, 3 times/week	Balance, power, number of falls (weekly assessment), walking ability	↑ flexibility, power, balance, walking ability; ↓ number of falls by 12.1%; ↔ CON
Izquierdo and Hakkinen 2001	11 older men, no controls	Same as Hakkinen et al 1998	16 weeks, 2 days/week	Muscle CSA, half squats, bench press, KE, KF,	↑ CSA, ↓ body fat, ↑ serum cortisol levels, ↑strength and power

				hormonal levels, 1 RM strength	
Katula and Rejeski 2008	45 M+W (75+) - into 3 groups ST PT CON	LE and UE strength and power training with dumbbells and pneumatic resistance	12 weeks, 3 times per week-3 sets of 8 to 10 reps	KE and leg press, self efficacy for strength, satisfaction with physical function and life satisfaction	↑LEP more in PT, power relates to function
Marsh and Miller 2009	45 M+W randomized to PT, ST and CON.	KE, leg press, upper limb exercises with dumbbells and machines	12 weeks, 3 times per week	KE and leg press using pneumatic machines, SPPB, DEXA, CT	18-25% ↑ muscle strength in both the groups, ↑ power only in power training group
Miszko and Cress 2003	39 older M+W randomized to ST (n=13), PT (n=11) or control (n=15)	Control group-daily activities and attended lectures Exercise groups-whole body exercises at different speeds.	16 weeks, 3 times per week	Physical function test, muscle strength and anaerobic power	↔ Power between groups, function improved in PT as compared to strength and control groups, ↑ ST in ST and PT groups
Orr and de Vos 2006	Older adults (69 years) (n=25) randomized to either one of the three training groups or control group	Training group: Resistance training for strength, power and muscle endurance using Keiser pneumatic resistance equipment CON: No active treatment	10 weeks, 2 times per week, 3 sets of 8 reps	Balance system to measure balance, muscle strength, power, velocity, muscle endurance, FFM	Low load power training ↑ balance. High velocity ↑ balance performance

Petrella and Kim 2007	31 young controls (16 M, 15 W), 30 older (14 M, 16 W)-60-75 years	KE, leg press and squat	16 weeks, 3 times a week	Thigh lean mass, total body lean mass, and body fat percentage using DEXA, KE 1 RM and bilateral MVC, surface EMG	29% ↑ KE B/L MVC in older adults, 27% ↑ in younger adults. Both older and younger adults ↑ isometric specific strength by 20-24% and dynamic specific strength by 32-34%. 88% ↑ power and 78% ↑concentric velocity by 8 weeks for older adults
Reid and Callahan 2008	57 community dwelling older adults- 1. PT (12W,11 M) 2. ST (13W, 9 M) 3. CON (6W, 6M)	Leg press, individual KE- PT: as fast as possible ST: slow and controlled CON: LE ROM and flexibility	12 weeks, three times a week	1 RM strength tests for LP and left and right KE, DEXA	↔ between groups
Sayers and Bean 2003	30 W (65+) randomized to HV and LV groups	Leg Press and individual KE	16 weeks, 3 times per week-3 sets of 8 reps	MMSE, PASE, GDS, balance tests, chair rise time, stair climb time, habitual and maximal gait velocities, disability outcomes	↔ between groups
Sayers and Gibson 2010	38 community dwelling older men and women PT: 13	PT: 3 sets of 12 - 14 repetitions at 40% 1 RM ST: 3 sets of 8 to 10 repetitions at	3 times per week for 12 weeks	LP, KE 1 RM – Keiser pneumatic equipment	Power training improved muscle strength and peak velocity. Strength training did not improve velocity.

	ST: 13 CON: 12	80% 1 RM CON: Warm up and stretching			
Signorile and Carmel 2002	24 W (61-75 years) randomized to HV(n=9), LV (n=8) and controls (n=7)	KF, KE, ADF, APF-training using isokinetic dynamo-meter using high velocity (HV group) and low velocity (LV group). Control group: stretching exercises on machine.	12 weeks, 3 times per week- HV for KF,KE- 4.73 rad/sec; HV for ADF, APF- 3.14 rad/sec; LV for KF, KE, ADF and APF-1.05 rad/sec	Power at 1.05, 3.14, 4.73, 5.24 rad/sec using isokinetic dynamometer	↔ between groups for KF at both velocities; KE ↑ at high and moderate velocities; ADF power ↑ both high and low velocities; APF ↑ low velocities only; ↔ CON
Stengel and Kemmler 2005	53 osteo-porotic post menopausal older women PT (n=25) ST (n=28)	Weight lifting, gym based exercises, co-ordination, strength, endurance, flexibility, home based exercises with rubber bands	12 months, 4 times per week	DEXA for BMD, Strength	PT > ST at maintaining BMD at spine and hip
Webber and Porter 2010	50 mobility impaired community dwelling older women, randomly assigned to three groups-	<u>Exercise group:</u> Perform ankle exercises “as fast as possible” with elastic bands or weighted machines (calf trainer)	12 weeks, two times a week , 45 minutes per session	Foot reaction time and movement velocity using the Lafayette timer, DF and PF torque, position and velocity using dynamo-meter	↓ Movement time by 12% in the band group, while ↔ in the other two groups; ↑PF strength and power in the weights group

	weight training (n=17), elastic band training (n=17), control group performing upper limb exercises (n=16)	<u>Placebo control group:</u> Static neck stretches, shoulder range of motion exercises and postural education			

Note: W=Women; M=Men; HV=High Velocity; ST=Strength Training; CON=Controls; RT=Resistance Training; BAL=Balance Training; COM=Combined; PT=Power Training; LV=Low Velocity; TKD=Taekwondo; ERT= Elastic Resistance Training; LE=Lower Extremity; KE=Knee Extension; APF= Ankle plantar flexion; LP= Leg Power; KF=Knee flexion; HE=Hip extension; HA=Hip abduction; ADF =Ankle dorsiflexion; EE= Elbow extension; EF= Elbow flexion; TE= Trunk extension; UE=Upper extremity; ROM=Range of Motion; TUG=Timed-up-and-go-test; PPT=Physical Performance Test; MMSE=Mini Mental Scale Examination; RM= Repetition Maximum; SAT-P= Satisfaction Profile; LEP=Leg Extension Power; PA= Physical Activity; EMG=Electromyography; BMD=Bone Mineral Density; DEXA=Dual X-ray Absorptiometry; MVC=Maximum Voluntary Contraction; PASE=Physical Activity Scale for the Elderly; GDS=Geriatric Depression Scale; RFD=Rate of Force Development; SPPB= Short Physical Performance Battery; Reps= Repetitions; GH=Growth Hormone; RFP=Rate of Force Production; MI=Mobility Impaired; B/L= Bilateral; ↑=Increase; ↓= Decrease; ↔ = No difference; Wks=Weeks; FFM=Fat Free Mass; CSA=Cross-sectional Area

In most studies, power training had positive benefits for older adults like increased neuromuscular power as measured by maximal voluntary contractions (Hakkinen et al, 2000; Earles et al, 2001; Izquierdo et al, 2001; Fielding et al, 2002; Signorile et al, 2002; Hruda et al, 2003; Bean et al, 2004; de Vos et al, 2005; Bottaro et al, 2007; Petrella et al, 2007; Katula et al, 2008; Iwamoto et al, 2008; Marsh et al, 2009; Sayers and Gibson, 2010; Webber and Porter, 2010), increased physical performance and function (Earles et al, 2001; Hruda et al, 2003; Miszko et al, 2003; Bean et al, 2004; Bottaro et al, 2007; Katula et al, 2008), improved movement time (Webber and Porter, 2010), increased balance (Orr et al, 2006), a decrease in the risk for falls (Iwamoto et al, 2008), and a decrease in bone loss (Stengel et al, 2005) and body fat (Izquierdo et al, 2001).

The review by Raj et al (2010) brought out many positive aspects of power training for older adults. The authors were of the opinion that, although conclusive evidence is still not available as to which training program is "the best" for older adults, to date, "power training has been found to be at least as useful as strength training in improving functional capacity in older adults"(Pg. 87). Power training can be an efficient and time saving method to improve strength as well as power in older adults (Marsh et al, 2009). Fielding et al (2002) conducted a randomized controlled trial to note which type of resistance training program would increase peak power in older women. It was found that high velocity power training increased leg extensor peak power nearly twofold more than the low velocity strength training program. A similar finding was found by Signorile et al (2005). The randomized controlled trial by Bottaro et al (2007) showed that inactive older men increased peak power and function only when they trained at higher velocities for power and not when they trained at lower velocities for strength. Sayers and Gibson

(2010) conducted a randomized controlled trial on 38 community dwelling older men and women and found that power training not only increased strength but also caused improved peak power and velocity. These later changes were not seen with strength training.

However, some studies have found that there is no differing effect of strength and power training on physical function in older adults (Earles et al, 2001; Bean et al, 2004; Reid and Callahan, 2008; Henwood et al, 2008). In any of these studies whether strength and power training are compared, it is not clear as to how the subjects trained differently, although the instructions were different. For instance, the velocity at which they trained could have been quite similar. Thus, studies need to be done to note the differences, if any, between these two types of resistance training programs.

2.2. Resistance training equipment

Many types of resistance training equipment have been used to train strength and power in older adults like Keiser pneumatic equipment (Morganti et al, 1995; Jozsi et al, 1999; Fielding et al, 2002; Sayers et al, 2003; Bean et al, 2004; Liu-Ambrose et al, 2004; de Vos et al, 2005; Katula et al, 2008; Reid and Callahan, 2008), dynamometers (Capodaglio et al, 2005; de Boer et al, 2007), leg press machine (Izquierdo et al, 2001; Earles et al, 2001; Bottaro et al, 2007; de Boer et al, 2007; Katula et al, 2008; Marsh et al, 2009), chest press machine (Izquierdo et al, 2001; Bottaro et al, 2007), knee extension machines (de Boer et al, 2007; Katula et al, 2008; Marsh et al, 2009), seated calf machine (de Boer et al, 2007), ankle resistance machines (Webber and Porter, 2010), body weight and elastic resistance bands (Aniansson et al, 1984; Topp et al, 1993; Mikesky et al, 1994; McMurdo and Johnstone, 1995; Skelton et al, 1995; Krebs et al, 1998; Damush and Damush, 1999; Rogers et al, 2002; Baum et al, 2003; Hruda et al, 2003; Yamauchi et al, 2005; Stengel et al, 2005; Colado and Triplett, 2008; Webber and Porter, 2010), and free weights (Judge et al, 1994; Skelton et al, 1995; Nelson et al, 2004; Liu-Ambrose et al, 2004; Liu et al, 2007; Katula et al, 2008).

Resistance training machines like pneumatic resistance equipment and dynamometers have the advantage of providing readings for various variables tested like work, power, force, and velocity. Training with larger absolute loads with correct body mechanics is possible with these machines (Seguin and Nelson, 2003); however access to these machines is expensive and they require facilities. It is difficult to incorporate these machines into community exercise programs (Colado and Triplett, 2008). Also, the sequence of muscle contractions produced when a resistance machine is used may not be similar to the physiologic muscle contraction because "exercise machines incorporate a fixed movement pathway; there is little activation of synergist muscles that contribute to strategies involved in functional performance" (Pg. 524, Sayers, 2007). These machines are not portable and take up a lot of room for storage. They are costly and are difficult to include in a home-based resistance exercise program (Page and Ellenbecker, 2003). In contrast to this, body weight, free weights and elastic resistance bands can exclusively be used by older adults during home-based and community-based exercise programs as they are relatively low-priced, portable, and take up less space. In particular, elastic resistance bands have been used in a wide range of individuals with favorable outcomes (Cordova et al, 1999; Hostler et al, 2001; Wallace et al, 2006; Davies et al, 2007; Jakubiak and Saunders, 2008; Rhea et al, 2009).

2.2.1. Elastic resistance bands

2.2.1.1. Advantages of elastic resistance bands

Elastic resistance bands are cost-effective (Simoneau et al, 2001), especially when considering training of those older adults who do not have sufficient income. Older adults can train at their convenience and this may facilitate compliance with the training program (Page and Ellenbecker, 2003). It is easy to exercise in a protected way by manipulating the length of the elastic band in order to achieve a particular level of resistance. In addition, and unlike free weights, the direction in which the resistance is applied is dependent on how these bands are aligned (Page and Ellenbecker, 2003). The study by Capodaglio et al on older men in Italy (2002) reported that the subjects took 2 seconds to complete one repetition of the same exercise using elastic resistance bands as compared to 6 seconds on an isotonic resistance machine. The resistance provided by the elastic resistance bands is less, which allows for a greater number of repetitions (Hostler et al, 2001). Additionally, these bands are portable and have high external validity (Damush and Damush, 1999). The study by Lubans et al (2010) found that in adolescents, as compared to weight training, the adherence to exercises with elastic resistance was higher, thus reducing the dropout rates.

Several studies have been conducted on older adults using these bands and beneficial effects like improved physical fitness (Aniansson et al, 1984), significant improvements in function (Baum et al, 2003; Yamauchi et al, 2005), modest increases in fat free mass (Colado and Triplett, 2008) and muscle power (Hruda et al, 2003; Webber and Porter, 2010), improvement in the fear of falling, balance and ankle dorsiflexor strength (Topp, 1996; Ribeiro et al, 2009), and faster movement time (Webber and Porter, 2010) have been demonstrated. The strength of exercised muscles in older adults improved post resistance exercise programs with these bands (Judge et al, 1994; Mikesky et al, 1994; Skelton et al, 1995; Damush and Damush, 1999; Rogers et al, 2002; Stengel et al, 2005; Ribeiro et al, 2009).

2.2.1.2. Use of elastic resistance bands to obtain high velocity power production

Since elastic resistance bands do not produce much resistance (Holster et al, 2001; Wallace et al, 2006), they could allow for a greater training velocity when used for power training. Some studies have supported this idea. The study by Webber and Porter (2010) on older women found that an elastic band training program for the ankle caused a significant improvement in the movement time. In this study, the older women who exercised with elastic bands significantly improved their movement time by 12% as compared to controls and those who trained with weights, probably due to the high velocity/ low load training provided by these bands. As compared to weights, elastic resistance bands provide lower resistance in the initial part of the range of motion (Capodaglio et al, 2002). In addition to this, the master's study by Turcotte (2005) found that elastic resistance bands produce greater acceleration at the initial ranges of motion, possibly due to minimal inertial resistance and less tension in the band. Thus, in order to increase velocity in the initial ranges of motion and consequently increase power, these bands seem to be promising tools. During power production, there is less time to exert force (Bean et al, 2002). An increase in velocity in the initial ranges could have several functional advantages to older adults, especially when a situation demands a quick reaction like pressing the brakes of the car to prevent a crash or avoid a fall.

2.2.1.3. Disadvantages of elastic resistance bands

Although elastic resistance bands have several advantages for power training as well as strength training in older adults, certain disadvantages need to be taken into consideration. Since the resting length of the band determines the resistance provided by the band, the intensity or the force provided by the band during exercise cannot be determined objectively (Simoneau et al, 2001) and consequently, the possibility of prescribing medium and long term training programs may restrict the widespread application of the bands. The color of the band is not a clear indicator of the resistance the band provides (Simoneau et al, 2001). “There may be a ceiling for the amount of resistance that can come from the bands” (Pg. 271, Wallace et al, 2006). Hence, elastic resistance training may not be as effective as weight training in inducing hypertrophic responses (Holster et al, 2001).

Whether the band provides linear resistance throughout the range of motion (Patterson et al, 2001; ACSM, 2007) or linear resistance through most of the range of motion with variable resistance initially (Simoneau et al, 2001) or if net torque production changes as the joint angle and the leverage changes (Hughes et al, 1999) is still debatable. Thus, there is a lack of consensus on the mechanics of force production with elastic bands; also, it is not clear as to how these bands could possibly affect the training velocity, which forms the core component of power training programs.

3. Training velocity and its functional implications

Velocity plays a very important role in the smooth and injury-free execution of functional movements in older adults (Sayers et al, 2007). With aging, there is a greater decrease in velocity, as compared to force (De Vito et al, 1998; Cuoco et al, 2004). Even if the muscle had adequate mass but was deficient in the required speed, it could have important functional consequences like unstable gait and posture, thus increasing the risk for falls and subsequent injuries (Sargeant, 2007). Clémencon et al (2008) measured maximal leg power (knee extensions), velocity and torque in older women residing in community retirement homes. On running a correlation analysis, it was found that velocity played an important role in physical performance like chair-stand time ($r = -0.414$) and stair-climb time ($r = -0.498$). The review by Raj et al (2010) demonstrated how velocity is important for functional performance in older adults. Cuoco et al (2004) conducted a cross sectional study on older adults in order to note the effect of velocity on function. It was found that higher velocities had significant associations with habitual gait velocity, chair rise time and stair climb time. "Activities such as level walking that require a much lower percentage of maximal strength to perform compared with stair climb or chair rise might be more sensitive to reductions in velocity or power output at low external resistances with advancing age" (Pg. 1205, Cuoco et al, 2004).

The pilot study by Sayers et al (2007) demonstrated that high training velocity was perceived as less laborious than traditional resistance training exercises, which are performed at lower velocities. The high velocity resistance training program was found to be associated with a reduced total workload per exercise session, which may be beneficial to older adults in terms of energy conservation (Norris et al, 2007; Henwood et al, 2008). In addition, high velocity training programs have been found to be a “safe” method of increasing power in older adults (Henwood et al, 2005; Bottaro et al, 2007; Marsh et al, 2009). Hence, for older adults, high velocity training program could be perceived as a more “comfortable” exercise regimen and the adherence to this kind of a program is expected to be more than the traditional resistance training program, thus producing long term benefits.

de Vos et al (2008) conducted a randomized controlled trial in older adults using pneumatic resistance. While testing for the relationship between training velocity and increases in power in older adults, it was found that post 10 weeks of power training, the velocity at peak power did not differ significantly between the groups. However, the training intensity was increased on a weekly basis, which could have possibly provided a training stimulus to low intensity groups, thus aiding in force gains rather than velocity. Also, the older adults with lower initial velocities had the greatest improvements in power production. Macaluso et al (2003) performed a 16 week training study with older women, which involved three different types of resistance exercise programs: high velocity training, low velocity training and combined training programs. It was found that there were no differential improvements in power and strength with high speed and low speed cycling programs. This study, too, had certain limitations. The training velocity was set too low for it to produce any significant changes, and the power output, after each session, was not thoroughly monitored.

Velocity-specific training was found to be optimal in young Taekwondo athletes while training for quick kicks (Jakubiak et al, 2008), and in collegiate athletes while training for jumping power (Rhea et al, 2009). However, the optimal training program for older adults is yet to be known. In order to train at different velocities, most of the researchers have used different verbal instructions for the concentric phase of movement ("as fast as possible" for power training and "slow and controlled" for strength training) (Bean et al, 2004; Bottaro et al, 2007; Henwood et al, 2008; Hruda et al, 2003; Reid and Callahan, 2008; Webber and Porter, 2010). A pilot study done on community dwelling older women (Webber and Porter, unpublished work) looked at the training velocities with power training using elastic resistance bands. Two subjects were chosen and their average training velocities (see Table 2) were determined by video motion analysis.

Table 2. Summary of velocities from pilot study (Webber and Porter)

	Dorsiflexion	Plantar flexion
Subject 1	20 degrees/second	37 degrees/second
Subject 2	42 degrees/second	80 degrees/second

Thus, it was found that, despite giving similar instructions to the subjects, they trained at different velocities. It was also seen that power training seemed highly variable because despite giving the same instructions, the older adults performed the movement at drastically different velocities during power training. This could be because the older adults did not perceive (or imagine) the fast movements as being faster than the slower ones and/or as fast as those perceived by younger adults. Also, due to the changes in the neuromuscular system with aging, they might not be physiologically able to go fast when given instructions to do so. Few studies have touched upon these issues. In a recent article published by Personnier et al (2010), it was stated that there is a greater decline of the ability to temporally perform imaginary walking in older adults as compared to younger adults. The intention to perform a fast movement is as important as actually performing the movement at a fast pace (Behm and Sale, 1993). However, in the study by Guillot et al (2006), on young sport students, it was found that EMG activity was significantly less while performing elbow flexion and extension exercises, when these exercises were imagined as compared to when they were performed actively, which was also mentioned in the review by Gabriel et al (2006). Thus, there is lot of inconsistency in research on older adults to see if they are able to perform faster contractions when instructed to – taking into consideration the "cognition of effort" issues (John et al, 2009) that we might encounter in older adults.

To date, it is not known whether older adults effectively respond to different verbal instructions, and therefore differentiate between strength and/or power accordingly. Hence, whether subjects performing strength training actually train at different velocities from those who are power training is yet to be known. Secondarily, it would be interesting to look at the differences, if any, in variability between strength and power training. The responses to resistance training are highly variable and there is a huge inter-individual variability when it comes to responses to resistance training (Hubal et al, 2005). Also, power training by itself seems highly variable in older adults (see Table 2) and strength training may be less variable because patients are most often prescribed strength training exercises and power training is quite often not prescribed in a community rehabilitation set up. So, it may be easier and thus less variable to perform strength training as compared to power training.

4. Objectives

1. To determine if there are any differences between the training velocities of older adults using elastic resistance bands of appropriate loads for strength training (“controlled”) and power training (“as fast as possible”).
2. To quantify the full range of training velocities for the ankle in a group of community dwelling older adults.

5. Hypotheses

1. Power training (“as fast as possible”) with elastic resistance bands will be done at a faster velocity than strength training (“controlled”) with bands, although there will be a wide range of training velocities used for each type of training.
2. Strength training will be less variable in velocity than power training.

6. Methods

6.1. Subjects

The subjects were recruited from the community dwelling older patients, 65 years and older, who attended the day hospital rehabilitation program at Riverview Health Centre, Winnipeg, Canada. According to the Riverview Health Centre research procedures, potential subjects were approached by the staff at Riverview Health Centre to see if they were interested in hearing about the study. Only those who were deemed to meet the pre-established criteria for eligibility were approached (see below for criteria). Those interested were then given letters of invitation (see Appendices 1 and 2) and other study materials (consent form and questionnaire; see Appendices 3 and 4). Interested individuals met the study researchers at the Day Hospital itself for final screening, any questions they might have had, to provide written informed consent and to schedule their first session. Once they showed interest to be included into the study, then personal information was collected (name, address, phone number, age, gender, etc) and screening questions as per the screening questionnaire (see Appendix 5) were asked. Exclusion criteria included any patient who had already participated in power and strength training of the ankle musculature, more than once a week, in the past 6 months, cognitive impairment (as per Riverview's outpatient policy, any patient suspected with cognitive impairment has cognitive testing done and noted in their files; such patients who had cognitive impairment were supposed to be excluded), any condition that precluded exercise (e.g. an acute condition like a recent myocardial infarction) or any neuromuscular condition that affected movement control (e.g., multiple sclerosis, Parkinson's disease, etc.). All other medical conditions were determined by the screening questionnaire, as well as the general information questionnaire. The minimum sample size needed as per the sample size calculations was 8 subjects (see Appendix 6). However we aimed to recruit 10 subjects, because our sample would consist of older patients attending a day rehabilitation program and we wanted to account for possible drop outs, which might undermine the statistical power of the study. Ethics approval was obtained from the Education and Nursing Ethics Board, University of Manitoba and research access was obtained from Riverview Health Centre.

6.2. Study design

During the first session, ankle dorsiflexion isometric strength was measured. Based on dorsiflexor strength, the appropriate color of bands was decided upon for dorsiflexor and plantar flexor strength and power training for each individual, and several familiarization trials were done. During the second session, the order of exercises was randomized for each subject. The same order of exercise was followed for subsequent sessions, for the particular subject. From the second session onwards, each subject performed 8 repetitions each of dorsiflexor and plantar flexor strength and power training. In the last session, the strength of the ankle dorsiflexors was again measured and one final training session was done.

6.2.1. Strength Testing

The strength of the ankle dorsiflexors was measured using a hand held dynamometer (MicroFet2 MT®, Hoggan Health Industries, Utah, USA; see Figure 1). The plantar flexors were not measured because plantar flexor strength measured by the hand held dynamometer is highly variable and "it is difficult to maintain the position of the hand held dynamometer on the metatarsal heads due to shape of the transducer head and the high force levels exerted by the plantar flexors" (Pg. 17, Clarke et al, 2011).

The instructions to the subject were read out from a script and the same script was used for all the subjects. The "make" test was used to measure maximal isometric dorsiflexor strength. It is preferred over the "break" test (Burns et al, 2005), as it is more reliable than the "break" test (Stratford et al, 1994; Burns et al, 2005). These are the two types of tests used to measure strength using hand held dynamometer. The "make" test measures the isometric strength by asking the subject to perform a maximal isometric contraction against a fixed dynamometer. The "break" test measures the eccentric strength as the examiner overcomes the maximal effort of the subject. At first, three sub-maximal dorsiflexor contractions were performed and then three maximal effort contractions were performed against the hand held dynamometer (see Figure 1) over 3 to 5 seconds each, with about one minute rest between contractions. The subjects were instructed to blow out so as to avoid breath holding during testing. The same tester measured dorsiflexor strength (of the left ankle for all subjects except one, for whom the right ankle was tested because he was left hemiparetic).

Figure 1. Position of the dynamometer over the foot during testing for ankle dorsiflexor strength.

6.2.2. Therabands

Strength testing was used to decide the color of the bands. The average of the three maximal isometric dorsiflexor contractions as measured by the hand held dynamometer was used to determine the load with which the ankle dorsiflexors can be trained. Using the table for elastic resistance pull forces (Page et al, 2000) provided by Thera-Band® elastic bands (The Hygenic Corporation, Akron, Ohio), the appropriate colored band was used to train the ankle dorsiflexors. Also, the next appropriate color was used to train the plantar flexors. The same length of band was used for dorsiflexion (32 inches) because the same set up was used for anchoring the band during dorsiflexion exercises (see Figure 2). For plantar flexion, the length of the band was equal to twice the leg length for each subject (as per standard guidelines on www.therabandacademy.com). The exercise bands of appropriate length were stretched 20 times before giving them to the subjects for exercise. Once the color and the length of the bands were decided upon, the subjects were taught to perform one set (consisting of 8 repetitions) each of strength and power training exercises for the ankle. The same instructor taught power and strength training using elastic resistance bands to all the subjects using the same instructions- “controlled (concentric) and controlled (eccentric)” for strength training and “fast (concentric) and controlled (eccentric)” for power training.

The colors used for dorsiflexion during the study ranged from yellow to green. The colors used for plantar flexion ranged from red to blue. No progression of the resistance was done during the training period.

6.2.3. Training protocol

From the second session onwards, one set of 8 repetitions was performed for strength training and one set of 8 repetitions for power training, for both ankle dorsiflexors and plantar flexors. There was a 30 second to one minute rest pause between sets for strength and power training. For power training, the subjects were instructed to perform the ankle movement “as fast as possible” during the concentric phase of exercise, whereas for strength training, the subjects were instructed to perform the ankle movement in a “controlled” way throughout the available range of motion.

It was a highly supervised exercise session with instructions given to all subjects for each repetition. Every session began at approximately the same time of day (morning for all subjects) for each subject throughout the study. All subjects were recruited at different points of time during the study which meant that they completed between 4 and 6 sessions. Both sides were trained in all subjects alternatively so that while one leg trained, the other leg was resting. However, only one side was filmed for each subject. The left lower body and leg were filmed for all subjects except one, for whom the right side was filmed because he was left hemiparetic.

6.2.4. Filming Protocol

6.2.4.1. Camera and marker positions

The subjects were filmed using a digital camcorder (Canon 200 MC Optura mini digital camcorder, Tokyo, Japan) which had a sampling rate of 30 frames per second. It was placed approximately 2 meters lateral to the filming leg, in order to capture a sagittal view of the ankle movement. The camera was affixed to a tripod (T120 Minipro Tripod, Optex, New Jersey, United States), such that the head was level to the ground. The position of the camera was noted down for each subject and every training session, the camera was placed in the same position.

In order to identify the hip, knee and the lateral border of the foot, markers were used. Markers were stuck onto the pants and the shoes of the subjects at the hip, ankle and the toe. An elasticized band was used for marking the knee. The position of the markers was measured with respect to bony landmarks and the markers were placed at the same place every time the subject came to exercise. Each subject was filmed for one set, each consisting of eight repetitions of ankle dorsiflexion and ankle plantar flexion, performed at the velocity at which they were trained, using the protocol mentioned above.

6.3. Motion analysis of the video footage

The video footage from the camera was downloaded into the computer using Canon software (AV/C Camera Storage Subunit-WIA Driver, Tokyo, Japan). Each video (consisting of 8 repetitions each of four movements – dorsiflexion strength training, plantar flexion strength training, dorsiflexion power training and plantar flexion power training) was split into 32 separate video files using Windows Movie maker. These video files were then analyzed using Proanalyst® Professional Edition - Version 1.5.4.0. (Xcitex, Cambridge, USA) to calculate the average and peak velocity, range of motion and peak acceleration. The reliability of making the measurements of velocity (average and peak), range of motion and peak acceleration was assessed in a separate test-retest study at a 1-week interval. The video files from 4 older subjects were used to determine the reliability of the velocity (average and peak), range of motion and peak acceleration, again at a 1-week interval. It was found that among all variables (average and peak velocity and range of motion), peak acceleration was highly variable for dorsiflexion strength (21.3%) and power (25.9%) training and plantar flexion strength (35.6%) and power (11.7%) training and hence it was excluded as a secondary variable for analyses (see Appendix 7).

For the analysis of the included variables, 2D feature tracking was done first at the toe, followed by the ankle and then at the knee (see Figures 2 and 3). Line tracking was used at the toe, ankle and the knee in order to determine the range of motion.

The instantaneous velocity value for each frame of movement was displayed by the software. They were exported into an excel sheet and the values of average velocity were calculated accordingly (as described in the data analyses section). The values of peak velocity were obtained from the excel sheets.

Ankle movement was divided into ankle dorsiflexion and ankle plantar flexion. Ankle dorsiflexion range of motion (displacement) was measured from the start of the dorsiflexion movement (i.e., from an ankle plantar flexed position) to the final frame of video beyond which the ankle did not dorsiflex. The position of maximum dorsiflexion (i.e., the point in the range of motion beyond which the ankle started plantar flexing) was the “end point” of ankle dorsiflexion.

Ankle plantar flexion range of motion (displacement) was measured from the start of the plantar flexion movement (i.e., from an ankle dorsiflexed position) to the final frame of video beyond which the ankle did not plantar flex. The position of maximum plantar flexion (i.e., the point in the range of motion beyond which the ankle started dorsiflexing) was the “end point” of ankle plantar flexion.

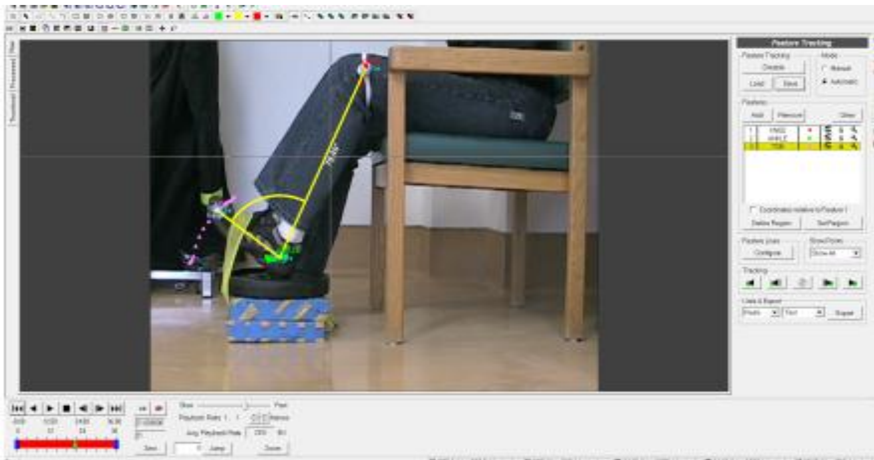

Figure 2. Analysis of a dorsiflexion repetition file.

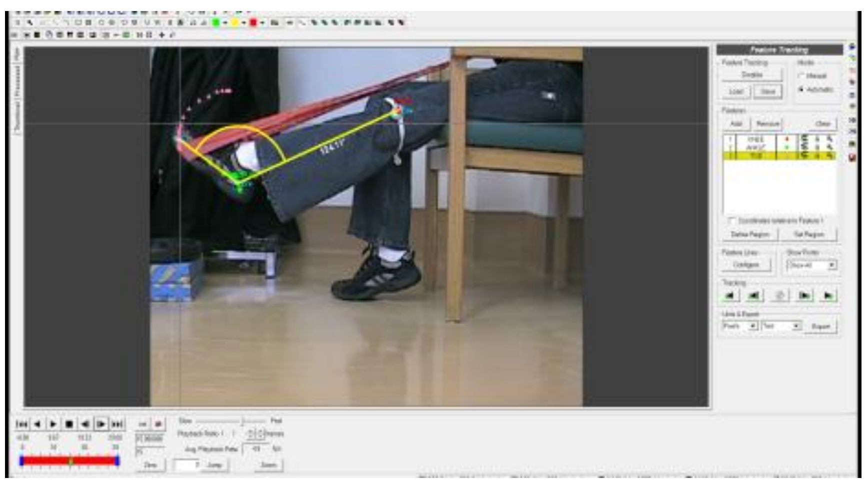

Figure 3. Analysis of a plantar flexion repetition file.

6.4. Data Analyses

The raw data files were used for analyses without use of any filter. However we used absolute value filter that would display the values as positive numbers, irrespective of the direction of movement. A total of 1336 repetitions were analyzed (a total of 1344 repetitions were filmed but 8 repetitions across all subjects, all of which were plantar flexion training, could not be analyzed because the toe marker was blocked by the band during movement). Once a single repetition file was tracked at the toe, ankle and knee marker positions, a graphical representation of each repetition file was done using the software and these data were then exported in to an excel sheet. Thus, the exported excel sheet would display values of instantaneous velocity and range of motion for each frame within that single repetition. Range of motion for that repetition file was calculated by subtraction of the minimum and the maximum values. Peak velocity for that repetition file was the highest value of the instantaneous velocity attained during that repetition. Since velocity was not normally distributed in every repetition (see Figure 4), the median velocity was used instead of average velocity for every repetition, in order to provide a representative velocity for each repetition. However, since the median values followed a normal distribution for velocity for the set (see Figure 5), averages of the medians were taken.

Complete data were available for all subjects for sessions 2, 3 and 4. However, some subjects completed more than 4 sessions up to a maximum of six. There was no substantial difference between the average values for sessions 2, 3 and 4, and the average values for all the completed sessions. Hence, the average values for each session were calculated and then the mean of all the completed sessions for each subject were used to calculate the final averages for the entire study for each subject.

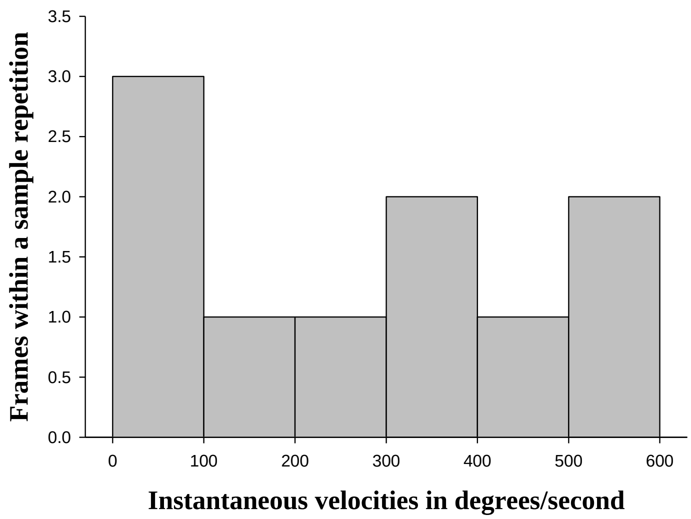

Figure 4. Histogram of the instantaneous velocities within a sample repetition for plantar flexion strength training.

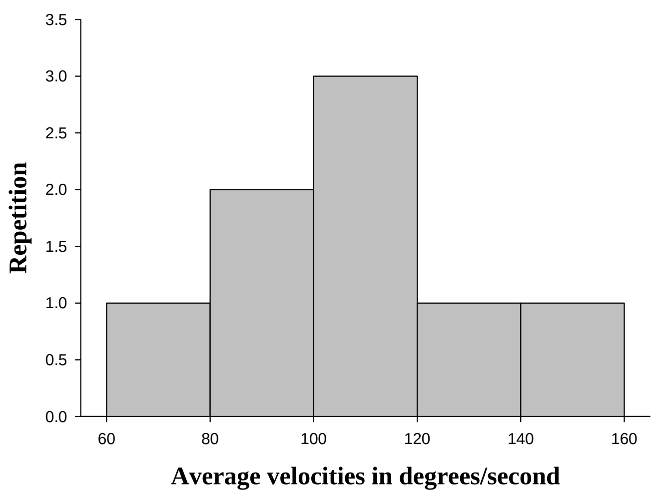

Figure 5. Histogram showing the averages of the medians of velocity for each repetition in a set during dorsiflexion power training.

6.5. Statistical Analyses

Data analyses were done using Sigma Stat (Version 3.10), Systat Software Inc., (San Jose, CA), SPSS (SPSS 15.0 SPSS Inc., Chicago, IL) and Statistica (Version 6.1, StatSoft Inc., Tulsa, Oklahoma) software. In order to check for changes in repetitions within a session, one way Repeated Measures ANOVA were used to note differences in median and peak velocities and range of motion within sessions. Since there was no consistent pattern within sessions, all repetitions were used in calculating the mean values for average and peak velocities and range of motion.

The primary outcome variable was plantar flexion and dorsiflexion angular velocity (average and peak) in degrees/second, reported as mean (peak velocity) and median (average velocity) values. Our primary hypothesis was power training would occur at faster velocities as compared to strength training. To check for differences between strength and power training in terms of velocity (peak and average) as well as range of motion as an explanatory variable, three way Repeated Measures ANOVAs were used to analyze the three factors, namely, type of training (strength and power), type of muscle group (dorsiflexors and plantar flexors) and time (between sessions 2, 3 and 4). Tukey's test was used for post-hoc analyses. The range of training velocities was obtained using the means for all completed sessions for each subject.

Our secondary hypothesis was that strength training would be less variable than power training. In order to determine the variability in terms of velocities during strength training and power training within a session, coefficient of variations (ratio of standard deviation and mean) were calculated for Session 4 for each subject and a two way repeated measures ANOVA (with two factors, namely type of training and type of muscle group) was the statistical test used to examine differences in variability. In order to determine the differences in dorsiflexor strength tested during first and last sessions, a paired t test was used. Effect sizes were calculated using a ratio of the standard deviation of the group means around the grand mean and the common standard deviation for each group (Portney and Watkins, 2009).

7. Results

7.1. Subjects

Thirteen subjects were informed about the research study by the physiotherapist at Riverview Day Hospital (see Figure 6) and all 13 subjects met with the study researchers. Out of these 13 subjects, one subject was deemed by the investigators to have some cognitive issues and hence excluded from the study. Out of the remaining 12 subjects, one subject developed acute swelling of the right lower leg during the second week and hence withdrew from the study due to his acute medical condition. Another possible subject consented to be a part of the study but did not come to the Day Hospital due to a conflict with the transit service and hence did not participate in the study. Another subject was hospitalized during the week when his second session was scheduled, and hence he too was excluded. Thus, the study was conducted with 9 subjects. The study aimed at once a week training for a period of 4 to 6 weeks. Only 4 subjects completed 6 weeks of the training program. Three other subjects completed 5 weeks (because they were recruited late into the study). Two subjects completed 4 weeks of the program (one subject was the last subject recruited into the study and the other missed one out of five sessions due to transportation issues). One subject missed two sessions, both because he fell sick, however he completed all 6 sessions. Another subject missed one session because of transit issues but completed all 6 sessions.

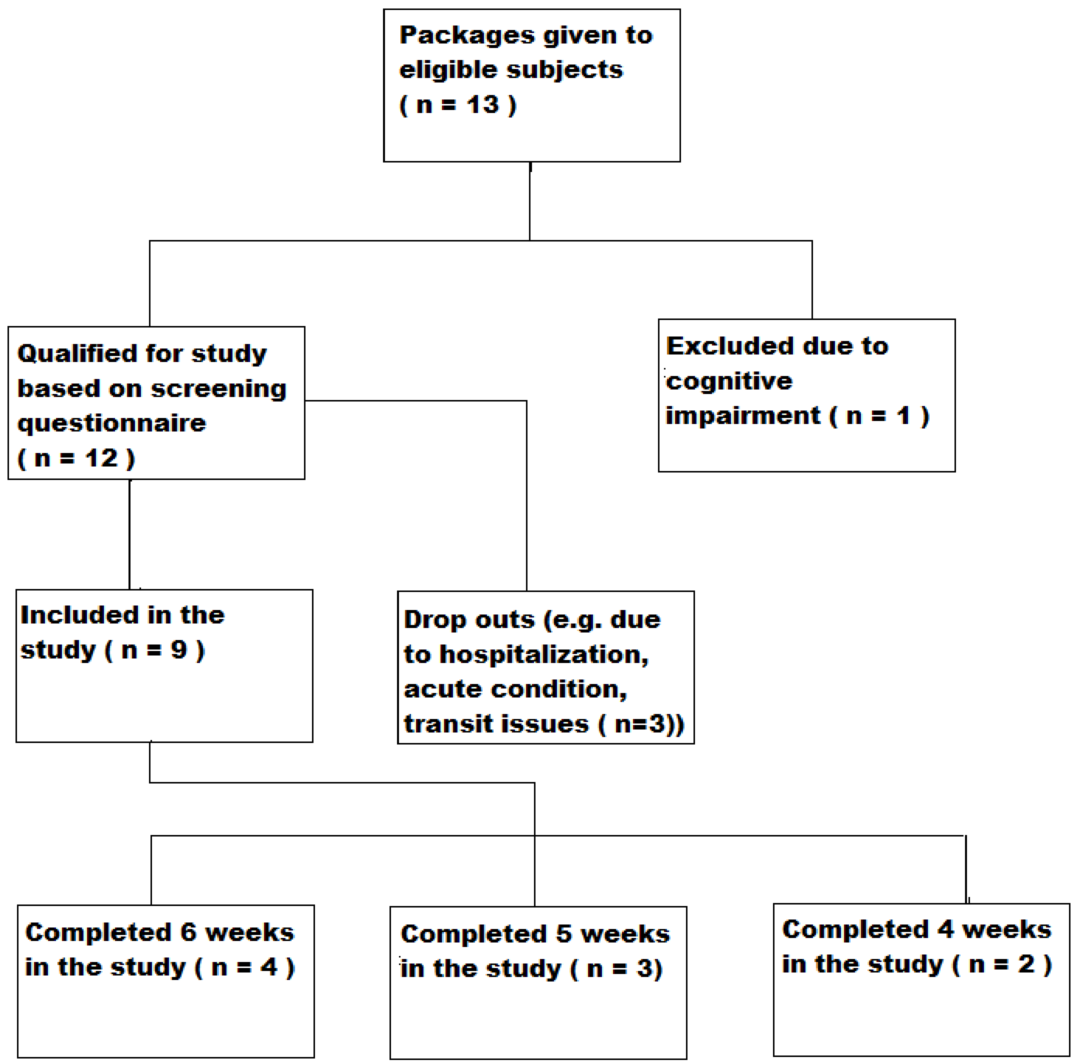

Figure 6. Flowchart outlining the recruitment process and the number of subjects in the study including drop outs.

Subjects in our study attended the day hospital for rehabilitation post hospitalization or based on referral from physician. The subjects ranged in age from 70 to 89 years. Two out of 9 subjects were males (22.2%). All except one subject (88.9 %) used walking aids. The majority of the subjects (77.8%) felt pretty good about their health, and were active in work and leisure. Almost 90% of the subjects perceived their health as fairly good for their age. All except three subjects (66.7%) had a fall in the past year and a little more than 50% claimed to be slightly forgetful. However, almost 70% were able to think and solve day to day problems (see Table 3).

There was only one subject who did not suffer from any long term conditions. The long term conditions that the subjects suffered from included high blood pressure, arthritis, heart disease, neck and back problems, cancer, osteoporosis, fibromyalgia rheumatic, stroke and pernicious anemia.

Each subject was taking at least two prescription drugs and the maximum was eight (see Table 3). The medications that were taken by the subjects were pain relievers, medications for high blood pressure and the heart, vitamins, steroids, xanthenes, antacids, calcium, narcotics, anti-depressants, diuretics, and anti-rheumatic drugs.

Table 3. Subject characteristics

Subject Characteristics	**Means/Medians**
Age	82±6 years
University or professional school education	45%
Activity level (in work and leisure)	Somewhat active (Median)
General health as per age	Good (Median)
Memory	Somewhat forgetful (Median)
Day-to-day problem solving	Able to think clearly and solve problems (Median)
Number of medications since past month	Two (Median)

7.2. Ankle strength

The average maximal isometric ankle strength was 107.0±34.8 N for the first session and 126.1±29.7 N for the last session. There was a significant change in the dynamometer readings between the first and last sessions (p=0.03). The mean difference between the first and last sessions was 24.4±14.8 N.

7.3. Training session data

7.3.1. Range of training velocities

A wide variability was observed between subjects in the velocities they trained at. There was overlap between the peak velocities during strength and power training of dorsiflexors (95.1 degrees/second to 226.3 degrees/second for strength training, and 147.3 degrees/second to 381.0 degrees/second for power training) and plantar flexors (107.1 degrees/second to 312.3 degrees/second for strength training, and 228.0 degrees/second to 657.5 degrees/second for power training) (see Figure 7A). This was also the case with average velocities during strength and power training of dorsiflexors (26.9 degrees/second to 81.9 degrees/second for strength training, and 41.3 degrees/second to 114.0 degrees/second for power training) and plantarflexors (44.1 degrees/second to 128.9 degrees/second for strength training, and 91.7 degrees/second to 301.4 degrees/second for power training) (see Figure 7B).

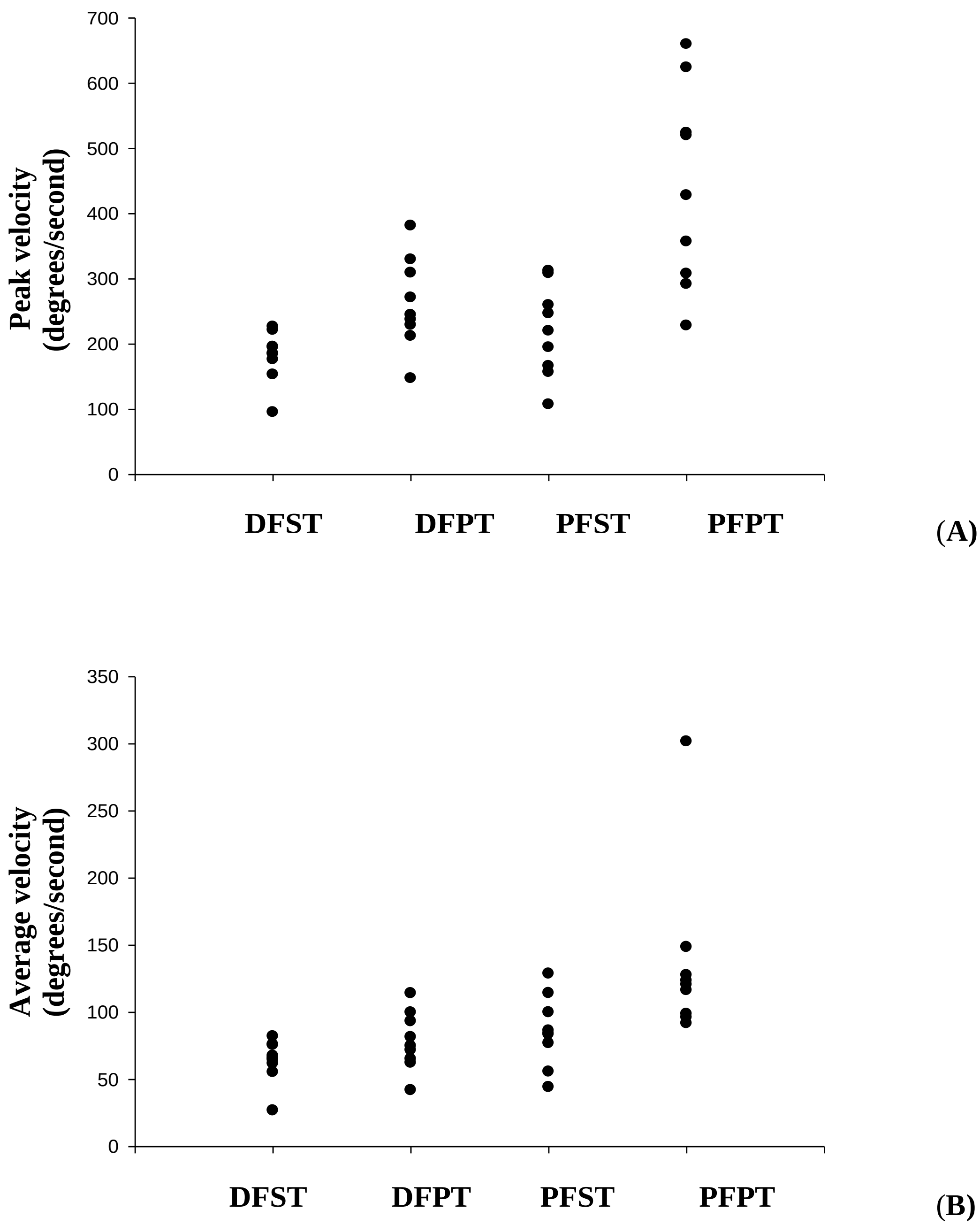

Figure 7. Scatter plots with the mean values of peak velocity (A) and average velocity (B) for each subject.

Note: DFST=Dorsiflexion Strength Training; DFPT=Dorsiflexion Power Training; PFST=Plantar flexion Strength Training; PFPT=Plantar flexion Power Training

7.3.2. Average velocity

A three way repeated measures ANOVA for three factors, namely, type of training, type of muscle group and time (session numbers 2, 3 and 4) was performed in order to detect differences and/or changes in average velocity. The main effects of type of training ($p<0.001$) and type of muscle group ($p<0.001$) were found to be significant for average velocity. The main effect of time was not significant. There was a significant interaction effect for type of training and type of muscle group for average velocity ($p<0.016$). The difference in average velocity between plantar flexion strength training and plantar flexion power training was 45.0%, while that between dorsiflexion and plantar flexion power training was 54.2%. Thus power training occurred at significantly faster average velocities as compared to strength training for plantar flexion (effect size 0.96) but not for dorsiflexion (effect size 0.53). There was no difference between average velocities for dorsiflexion and plantar flexion strength training (see Table 4).

Table 4. Average velocities (degrees/second) during training

	Strength Training	Power Training	p value (Type of training)
Dorsflexion	63.6±16.1	77.9±21.8	NS
Plantar Flexion	86.0±8.8	135.8±64.6	p<0.001
p value (Muscle group)	NS	p<0.001	

Note: NS=p>0.33

A paired t test was conducted in order to check the effect of the outlier on the overall significance on the differences between plantar flexion strength and power training for average velocity. The paired t test showed significant differences between strength and power training for plantar flexors ($p<0.003$), even after exclusion of the outlier (see Figure 8).

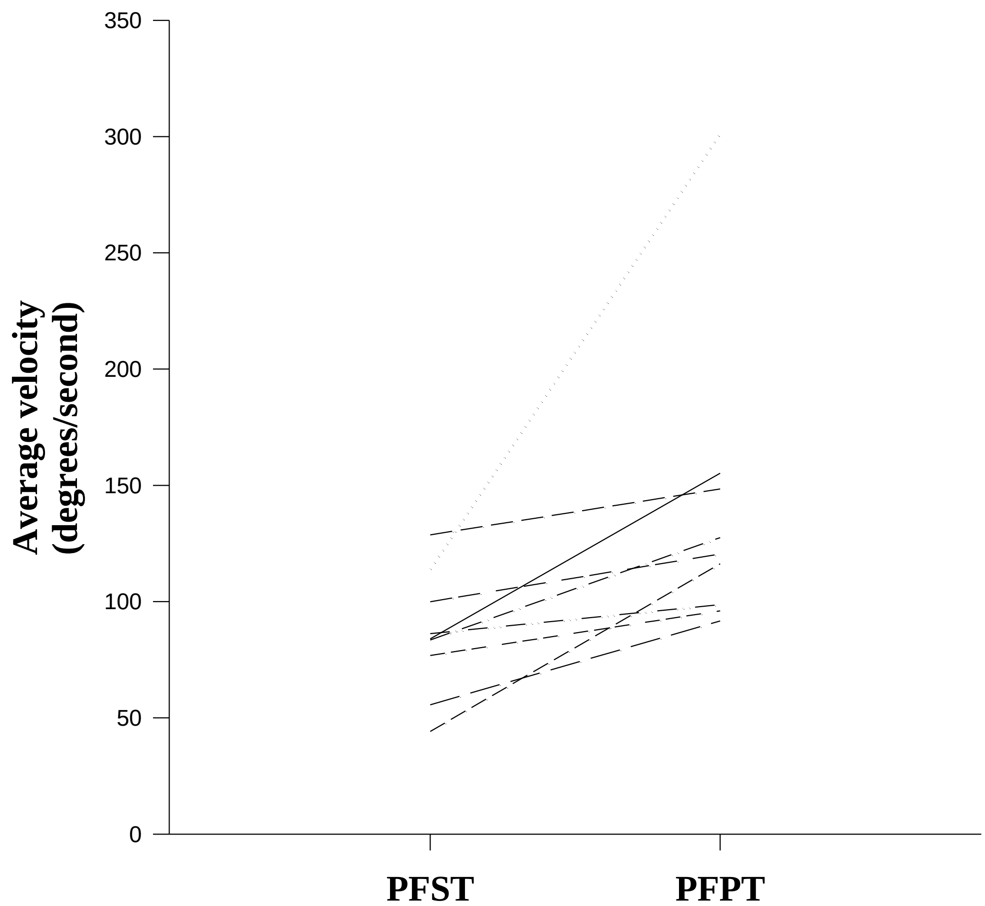

Figure 8. Individual values for average velocity during plantar flexion strength training (PFST) and plantar flexion power training (PFPT).

7.3.3. Peak velocity

A three way repeated measures ANOVA for three factors, namely, type of training, type of muscle group and time (session numbers 2, 3 and 4) was performed in order to detect effects on peak velocity. The main effects of type of training ($p<0.001$) and type of muscle group ($p<0.001$) were found to be significant for peak velocity. The main effect of time was not significant. There was a significant interaction effect for type of training and type of muscle group for peak velocity ($p<0.001$). The difference in peak velocities during strength and power training for dorsiflexors was 36.6% (effect size 1.11), and for plantar flexors was 66.7% (effect size 1.48), with power training occurring at faster velocities as compared to strength training. Plantar flexors developed higher peak velocities than dorsiflexors during power training by 50.3%. However, there were no significant differences between dorsiflexion and plantar flexion strength training (see Table 5).

Table 5. Peak velocities (degrees/second) during training

	Strength Training	Power Training	p value (Type of training)
Dorsflexion	181.4±36.9	262.2±65.7	p<0.016
Plantar Flexion	219.0±65.6	437.7±144.0	p<0.001
p value (Muscle group)	NS	p<0.001	

Note: NS=p>0.55

7.3.4. Range of motion

A three way repeated measures ANOVA for three factors, namely, type of training, type of muscle group and time (session numbers 2, 3 and 4) was performed in order to detect effects on the range of motion. Range of motion was not significantly different between sessions, types of muscle groups and types of training (strength and power) (see Table 6).

Table 6. Range of motion (degrees) during training

	Strength Training	Power Training	p value (Type of training)
Dorsflexion	36.5±8.9	35.0±7.4	NS
Plantar Flexion	39.8±6.8	42.7±6.3	NS
p value (Muscle group)	NS	NS	

Note: NS=p>0.49

7.3.5. Coefficient of variation (within Session 4)

On running a two way repeated measures ANOVA for Session 4, it was found that the main effects (type of training and type of muscle group) as well as the interaction effect (type of muscle group and type of training) were not significant for average as well as peak velocity (see Tables 7 and 8).

Table 7. Coefficient of variation values for average velocity

	Strength Training	Power Training	p value (Type of training)
Dorsflexion	0.24±0.10	0.25±0.10	NS
Plantar Flexion	0.27±0.08	0.34±0.10	NS
p value (Muscle group)	NS	NS	

Note: NS=p>0.12

Table 8. Coefficient of variation values for peak velocity

	Strength Training	Power Training	p value (Type of training)
Dorsflexion	0.22±0.16	0.14±0.06	NS
Plantar Flexion	0.22±0.06	0.21±0.08	NS
p value (Muscle group)	NS	NS	

Note: NS=p>0.20

8. Discussion

The purpose of this study was to determine if there were any differences in the training velocities when using elastic resistance bands for strength and power training of older patients attending a day hospital rehabilitation program. In this study, power training occurred at higher peak velocities as compared to strength training for both dorsiflexion as well as plantar flexion. As far as our knowledge goes, studies to date have not measured the velocity during strength and power training and it has been assumed that when older adults are instructed to perform movements "as fast as possible", they would perform the movements at higher velocities. This study validated the assumption that older patients attending a day hospital rehabilitation program could differentiate between strength and power training. However, there seemed to be overlap between strength and power training velocities, between individuals.

The two main outcome variables in our study were peak and average velocities. It was seen that the peak velocities for both dorsiflexion and plantar flexion were significantly different for strength and power training; however the average velocity during strength and power training was significantly different only for plantar flexion and not for dorsiflexion. The study was powered to detect differences in training velocity between strength and power training (primary hypothesis). Hence, the study was not powered enough (0.45) to detect changes in average velocity for dorsiflexion strength and power training, based on the differences and variability within subjects, seen in this study. On running a sample size calculation for detecting changes in average velocity between strength and power training for dorsiflexors, it was found that a minimum of 19 subjects would be required. When the effect size indices were calculated, it was seen that the effect size was a little more than medium effect (0.5) for differences in average velocities for dorsiflexion strength and power training, while for plantar flexion strength and power training differences; it was 0.96 which is much higher than a large effect (0.8).

There was one subject (outlier) who developed extremely high average velocities as compared to the other subjects during plantar flexor strength and power training. This subject was the youngest male patient (70 years) enrolled in the study that had relatively strong ankle muscles (an average of 183 N) as compared to the rest of the patients (an average of 108 N). Since strength is correlated with speed (Nimphius et al, 2010), this subject might have developed higher training velocities than the other subjects in the study because he was stronger. In addition, because he was younger, the contractile properties of his muscles might have been faster (Dalton et al, 2010).

Secondarily, when the differences between muscle groups in terms of average and peak velocities were considered, it was found that plantar flexors had higher average and peak velocities than dorsiflexors for power training. The force (Fukunaga et al, 1996) and torque (Gadeberg et al, 1999; Webber et al, 2010) produced by plantar flexors is greater than dorsiflexors. Again the greater the strength of a muscle, the greater is its ability to train at higher velocities (Nimphius et al, 2010) as compared to other muscles. However, the load for plantar flexor resistance training was objectively decided but not relative to the plantar flexor strength. For example, if a subject was prescribed a yellow band for dorsiflexion resistance training, the red band (next higher color) was used for plantar flexor resistance training. Hence, the differential loads used for the different muscle groups could have affected the actual velocities at which the subjects trained. The plantar flexors might have trained against lesser loads, probably enabling this muscle group to train at higher velocities than dorsiflexors. Despite the differences found in muscle groups, there was neither a decline nor an increase in average and peak velocity between sessions.

Since there were no differences in terms of training velocities between sessions, we used Session 4 in order to look at the differences in variability between strength and power training. Also, we expected Session 4 (among sessions 2, 3 and 4) to demonstrate maximum learning effects (Connelly and Carnahan, 2000). There were no significant differences between strength and power training in terms of variability. This was contradictory to what we had hypothesized. Since power as well as strength training control for velocity, it was found that there were no significant differences between strength and power training in terms of variability and that strength and power training were equally variable. We were looking at differences within a single session and the same instructor gave instructions for both strength and power training. Since each repetition was highly supervised, this could have contributed to the lack of significant differences in terms of variability between strength and power training. The subjects had never performed resistance training (both strength and power) for their ankle muscles and our resistance training program was a novel task to them.

To the best of our knowledge, the velocity values during resistance training have seldom been reported. Signorile et al (2002) conducted a study on older community dwelling independent women in order to compare the different effects of training speed on average power in the upper and lower leg. The subjects were trained 3 times a week for 12 weeks at 3.14 rad/s (close to 180 degrees/second) for ankle power training and 1.05 rad/s (close to 60 degrees/second) for ankle strength training on an isokinetic dynamometer. Also, knee power training was performed at 4.73 rad/s (close to 270 degrees/second) and knee strength training at 1.05 rad/s. Testing for average power was done at three different speeds, 1.05 rad/s, 3.14 rad/s and 5.24 rad/s (close to 300 degrees/second). It was concluded that for lower leg training (ankle muscles), lower training speeds improved average power more than higher training speeds. However, the average power for dorsiflexors improved similarly at both lower and higher training speeds and during plantar flexor training, the knee was in a flexed position due to which maximum increase in power was provided by the slow contracting soleus muscle. Although older adults in this study were trained at particular velocities using isokinetic dynamometer, it is not yet known if they were able to attain those high velocities as set on the isokinetic dynamometers.

A similar study was done on young college male students by Coyle et al (1981) to look at the differential increases in peak torque while performing knee extensions at different training speeds. The subjects were trained three times a week for 6 weeks using two different training speeds (60 degrees/second for slow paced training and 300 degrees/second for fast paced training) using an isokinetic dynamometer. It was found that subjects who trained at 300 degrees/second had increased peak torque not only at the training speed (300 degrees/second) but also at slower velocities (180 degrees/second); however the subjects who trained at slower velocities had maximum peak torque gains only at 60 degrees/second.

de Vos et al (2008) conducted a study on healthy older adults in order to examine the effects of training intensity on the contributions of force and velocity during explosive resistance training at 20%, 50% and 80% 1 RM. It was found that the contribution of velocity towards power development was similar between the three groups. Also, Earles et al (2001) found that velocity specific resistance training improved power more than strength training in healthy older adults, although there were no differing effects on function. Also, the loads that have been used in the above studies could have a substantial role to play in the velocities at which these older adults train (de Vos et al, 2005).

This study used elastic resistance bands as the training equipment. Higher loads have been shown to increase strength (de Vos et al, 2005, 2008) and lower loads could improve the velocity component of power (de Vos et al, 2008). Elastic bands generally produce lower loads (Wallace et al, 2006), and thus could have encouraged development of higher velocities in this population. In our study, the band color ranged from yellow to green for dorsiflexor training and red to blue for plantar flexor training. This color range has been used in previous strength training studies (McMurdo and Johnstone, 1995; Baum et al, 2003; Yamauchi et al, 2005). However, for power training, devices like the leg press machine (Hakkinen et al, 2000; Izquierdo et al, 2001; Earles et al, 2001; Fielding et al, 2002; Bean et al, 2004; Bottaro et al, 2007; Henwood et al, 2008; Katula et al, 2008; Marsh et al, 2009; Sayers and Gibson, 2010), pneumatic equipment (de Vos et al, 2005; Orr et al, 2006) and dynamometers (Hakkinen et al, 2001; Izquierdo et al, 2001; Signorile et al, 2002) have been used. While many studies have used elastic resistance bands for strength training (as mentioned above), few studies have used elastic resistance bands for power training (Webber and Porter, 2010). These bands have been more often used for home exercise programs rather than lab based training. Our study involved training of the patients in the community (at the day rehabilitation hospital) and these patients were already using elastic bands for strength training of other joints in the body other than the ankle. No other resistance training equipments were being used by these patients except cuff weights. Elastic resistance was also used as the training tool for practical reasons of portability, easy storage and easy handling techniques. Also, it has been suggested that for older adults, the training loads should be appropriate, in order to increase velocity of movement because "contraction velocity may be relevant to the optimization of exercise programs designed to enhance muscle power and delay the functional decline" (Pg. 1598, Clemencon et al, 2008).

Nevertheless, elastic bands have a major challenge in quantifying the forces produced by them in a community setting because the forces produced by the therabands depend on percentage elongation (Page et al, 2000), which is difficult to monitor. The same length of the dorsiflexor band (although the color of the band used was different for different subjects) was used for each subject because the setup used to anchor the band was the same. With plantar flexion, the length was again customized for each patient (twice the leg length of the subject) and the way the subject held on to the band was kept the same throughout the training study. In our study, we used a hand held dynamometer to measure ankle dorsiflexion strength and the appropriate color of the bands (as recommended by Theraband Company) was based upon the strength level for each person. However, the dynamometer measured the isometric strength which was higher than the isotonic forces that were needed to perform the exercise.

Hand held dynamometers have been validated for use in community dwelling older adults (Wang et al, 2002; Arnold et al, 2010) for measuring the strength of the ankle dorsiflexors (Ford-Smith et al, 2001; Takazawa et al, 2003; Arnold et al, 2010; Spink et al, 2010). In the study by Andrews et al (1999), normative values were found for 49 older adults between the ages of 70 to 79 years. Ankle dorsiflexor average strength values ranged from 210.5 N for older men to 153.4 N for older women, with the average being 181.95 N. The average ankle dorsiflexor strength values as measured by hand held dynamometer in the cross sectional study by Spink et al (2011) in 305 community dwelling older adults, 65 years and older, was 153.4±43.9 N on an average. In our study, the average value was 116.5 N. In the earlier studies, the subjects were asymptomatic community dwelling older adults while in our study, the subjects were older patients (70 to 89 years) attending a day hospital rehabilitation program. With the exception of one subject, all 8 subjects in our study suffered from at least two chronic diseases. Hence, the values in our study were likely lower because our sample was weaker and older, and predominantly female.

In addition, the position in which the testing was done was different. In the earlier studies (Andrews et al, 1999; Spink et al, 2011), in supine lying, the knee on the side tested was maintained in a straightened position with the foot just off the table. Thus, in these studies, the testing was done in a gravity eliminated plane. In our study, we had the subjects seated on a standard chair (18 inches height). The hip was flexed to 90 degrees and the thigh supported on the chair. The knee was in a flexed position (90 to 100 degrees) and the ankle in a neutral position. Thus, the testing was done against gravity and it might be difficult to obtain higher values as compared to the position in the earlier studies. The dynamometer that was used by Andrews et al (1996) was the Chatillon CSD400C hand held dynamometer, while the one used by Spink et al (2011) was the Citec hand held dynamometer and our study used the MicroFet2 MT® hand held dynamometer. Although no study to date has looked at the differences when using these hand held dynamometers for measuring dorsiflexor isometric strength, it has been noted that there exists a difference in the force recorded by different hand held dynamometers used to measure the strength of the same muscle groups (Click Fenter et al, 2003).

It was found in our study that the maximal isometric dorsiflexor strength improved by 18% when tested pre and post training program. This is comparatively lower than the strength gains that have been recorded in previous studies (32-34% - Petrella et al, 2007; 18-25% - Marsh et al, 2009). As there was no control group in the study, we cannot be certain that the increases could be attributed to our resistance training program. Our subjects were older patients who underwent rehabilitation at the day hospital (apart from our training program) that included warm-ups, walking, recreation and ankle mobility exercises. These exercises might have been sufficient to produce an increase in the neural output to the active muscle fibers (Gabriel et al, 2006), improvement in motor skills and eventual increased corticospinal excitability (Jensen et al, 2005). This might explain why the dorsiflexor strength improved over the 4 to 6 weeks of the training study. These strength changes could have affected the training velocities, since a stronger muscle could produce greater velocities as compared to a weaker muscle (Nimphius et al, 2010).

It would be interesting to look at the effects of strength and power training on function in older patients attending a day hospital rehabilitation program, when the actual training velocities are known. This could be achieved by conducting a randomized controlled trial and increasing the number and frequency of training sessions. The influence of training velocity on power and function could also be examined.

9. Summary

9.1. Strengths

This study had various strengths. It distinguished between strength and power training in terms of peak velocity. Although this was assumed in all the studies that have been done to date, this study is the first (to the best of our knowledge) to validate this assumption. Secondly, the training program as such made use of cost effective equipment and thus can be easily implemented in the community, especially for older adults and throughout the training program, every session was highly supervised wherein the same instructor gave instructions for each repetition at each session for each subject and the same order of exercise was followed during every filming session after initial randomization. Lastly, it was a within-person study due to which the variability was reduced.

9.2. Limitations and Future Directions

This study had a few drawbacks. The camera we used had a low sampling rate of 30 Hz. We lacked enough sample size to determine differences in average training velocities during strength and power training for dorsiflexors. Our sample size was based on the primary hypothesis due to which we needed more subjects in order to test the type of training versus the type of muscle group interactions. Thus, a larger sample size can be used to detect changes in average velocity with dorsiflexion strength and power training. Also, despite increases in dorsiflexor strength, the load for both dorsiflexion and plantar flexion training was kept constant throughout the study. This could have made it easier to develop higher velocities during power training; however the velocity did not change over the training period between sessions. In addition to this, the load that was used for plantar flexor resistance training was not relative to the plantar flexor strength because the strength of the plantar flexors was not measured. The load used for plantar flexion resistance training might not have provided enough resistance to the movement which might have caused higher velocity development for plantar flexors. However, comparing the muscle groups' actual training velocities was not a primary aim of this study. Future studies that compare different muscle groups to examine their training velocity potential should use relative loads that are more precisely determined. Plantar flexor strength could be measured using isokinetic dynamometers and an appropriate training load used for the plantar flexors as a result. The load could be periodically changed according to strength tests performed as required.

This study could also be done on different muscle groups such as the knee and hip muscles. It would be intriguing to see the actual power that is developed during community rehabilitation of these older patients. Also we could check if higher training velocities cause larger gains in power, and consequently the effects of training at higher velocities on functional outcomes like chair stands and timed-up-and-go-test that require greater power.

9.3. Conclusions

In conclusion, it can be said that power training occurred at higher peak velocities as compared to strength training in older patients attending a day hospital rehabilitation program. Although there was overlap between training velocities during strength and power training, older adults do have the potential to develop fast contractions when required during power training. Hence, researchers should monitor the velocity during different kinds of resistance training in older adults.

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APPENDICES

APPENDIX 1: Invitation Letter- Riverview Health Centre

RIVERVIEW
HEALTH CENTRE

Dear Patient

Re: Chance to participate in research project

Please read the enclosed material so you can decide whether you would like to participate in a research project. The project has been approved by a University or College Ethics committee and Riverview Health Centre's Research Committee.

Your name has not been given to the researcher. You will need to contact him or her. The researcher does not know who you are or have your contact information. He/she will not know about you at all if you choose not to be a part of the study. Your care here will not change regardless of your decision.

Research at Riverview: Because we want to provide the best possible and most up to date care to our patients and residents, our centre supports and participates in research. Before researchers are allowed to work with our patients and residents or with their information, the Riverview Health Centre Research Committee reviews their plans to make sure that they are in keeping with laws, policies and procedures and Riverview's mission and values. One of our staff may be assigned to work with the researcher or act as an investigator.

If you need to know more: If you wish to know more about the specific study after reviewing the information, please contact the researcher directly.

If you wish to know more about research at Riverview Health Centre and how projects are reviewed, please check our website www.rhc.mb.ca or call me at 478-6215.

Thank-you

John B. Bond, Jr., Ph.D.

Manager Research and

Advisor: Research and Applied Learning

Riverview Health Centre

1 Morley Avenue

Winnipeg, MB

R3L 2P4

phone: (204) 478-6215

e-mail: jbond@rhc.mb.ca

APPENDIX 2: Invitation letter- University of Manitoba

Date: ___________________________

Dear _____________________________________:

Thank you for your interest in our study. Enclosed you will find information about the study, and a consent form, and a questionnaire. Please read through the summary of the project and the consent form. On the next page you will see a chart outlining the steps of the study, if you do participate.

Once you have made a decision about whether you want to participate or if you have any questions, please contact us at 480-1487.

If you do agree to participate you can fill out the General/Medical Questionnaire, and bring it with you, along with the consent form, when we first meet at Riverview Health Centre.

Thank you again, and do not hesitate to ask any questions you might have.

Sincerely,

Michelle Porter, PhD

portermm@cc.umanitoba.ca

Pavithra Rajan

umrajan@cc.umanitoba.ca

The velocity of elastic band training study

Time-line for each subject

Receipt of information package and consent form

↓

Call us at 480-1487 to determine your eligibility and if you have any questions.

↓

Scheduling of initial meeting at Riverview Health Centre

- This will be done at a time when you would already be attending the program there
- Consent forms will be signed
- Ankle strength will be measured
- Ankle training will be demonstrated and taught

↓

Ankle training

- Each session will be videotaped (lower body only)
- This will be done for 3 to 5 weeks

↓

Final session (at 4 to 6 weeks)

- test of ankle dorsiflexion strength
- final session where ankle training will be videotaped

APPENDIX 3: Sample consent form

Research Project Title: The velocity of elastic band training

Researchers: Dr. Michelle Porter, Pavithra Rajan, Master of Science student

Sponsor: AUTO21, Network Centres of Excellence

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Summary of Project

The purpose of this study is to examine two different forms of exercise training, namely strength and power training and the way they are done with elastic bands, in older adults (≥65 years of age). We are specifically interested in studying the velocity that older adults use when they are doing power or strength training of the ankle muscles with elastic bands. This project will provide important information regarding different types of resistance training, and will also be the thesis project of Pavithra Rajan. The study will involve testing and training at the day hospital physical therapy program at the Riverview Health Centre, Winnipeg.

Before you participate in the study you will be asked to fill out the Informed Consent form, and our General Information Questionnaire. It will take you approximately 15 to 30 minutes to read through and complete these questionnaires. If you are eligible and interested in participating, your testing session will be scheduled in the day hospital itself at the Riverview Health Centre, Winnipeg.

In the first session, we will measure the strength of the muscles that move your foot up towards your shin. To do this we will use a small device that will be held by the tester against the top of your foot, and then you will pull up against the device. You will practice with submaximal contractions, and then 3 maximal effort contractions will be done, each over 3 to 5 seconds, with about 1 minute rest between contractions. This will take approximately 5 to 10 minutes.

After this testing in the first session, we will demonstrate and teach you the different types of training using the bands. For one movement you will pull your foot up against the band, and in the other you point your toes against the band. For both of these movements we will ask you to do them at slow and fast speeds.

In the next 3 to 5 sessions we will ask you to do the training movements that were taught in the first session. For each one you will perform one set consisting of 8 repetitions at a slow speed, and also one set consisting of 8 repetitions at a fast speed. This training will take about 5 to 10 minutes.

As a part of the training sessions, your lower body will be videotaped using a digital video camera placed approximately 2 meters away. This will occur during the usual training sessions and hence will not require any additional time on your part, and there will not be any additional risk. Also, the videotaping will only be done on your lower body, it will not show your face, so there would not be any identifying information other than the lower body and your shoes. This videotaping will only be done with the ankle exercises using the elastic bands and not your regular physical therapy session. In order to accurately measure the movement of your knee and ankle, markers will be used on clothes and shoes. These markers will be taped to your clothes and shoes at the hip, ankle and foot, and will easily be removed when the videotaping is done. The knee will be marked by placing a colourful elasticized band around it.

In the final session we will test your strength again using the same device as used in the first session. Also, one final training session will be done, with videotaping as described above.

Confidentiality

Each participant will be assigned an identification number. The ID number will be used for all paper documentation, computer files, and videos. Data forms for all subjects will be kept in a locked filing cabinet. Forms that include both participants' names and numbers will be kept in a different filing cabinet. All consent forms will be kept in a locked filing cabinet with no number. Videos will only include the subject's lower body, therefore, they will not be identifiable. The original video tapes will be kept locked in a file cabinet or safe, and any video files for computer analysis will be kept in a locked cabinet or on a password protected computer. The confidential data collected through this study will be kept securely for 7 years after publication before being destroyed. In any written documents (reports or publications) or presentations you will not be identified.

Benefits

Participating in this study will allow you to take part in supervised exercise sessions, free of charge, involving different types of exercises, which may be beneficial to you. You will receive information about how to perform these exercises safely. You will also receive information regarding your own abilities from the strength test and throughout the training period. After all the data is analysed we will mail you your results from the study, as well as the overall results.

Risks

Any type of physical activity has a certain level of risk associated with it. However, careful screening will be undertaken to ensure as much as possible that you are safe to participate. You will be supervised by highly trained staff during exercise testing and training procedures. Strength and power training for the ankle musculature has a low likelihood of severe injury. In older individuals, the incidence of injury is < 1 in 200 strength/power tests and approximately 1 in 400 ankle training sessions. Typical exercise-related injuries that could occur would include worsening of existing joint conditions (e.g. arthritis) or other joint abnormalities as well as minor strains of the dorsiflexor or plantarflexor muscles in the lower leg. If you agree to participate and experience pain or extreme discomfort during any part of a testing or training session, you should let us know and exercise will be immediately discontinued.

Consent Form

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time (in person, over the phone or in writing with the researchers listed below), and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. If you do withdraw your data would be destroyed. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

Dr. Michelle Porter, Principal Investigator 474-8795

Pavithra Rajan, Master's Student 480-1487

This research has been approved by the Education/Nursing Research Ethics Board. **If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Secretariat at 474-7122, or e-mail margaret_bowman@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.**

______________________________ Participant's Name (print)

______________________________ Participant's Signature / Date

________________________________ Researcher and/or Delegate's Name (print)

__________________________________ Researcher and/or Delegate's Signature Date

APPENDIX 4: General Information Questionnaire

General Information Questionnaire

1. What is the highest level of education you have attained? (Please mark one)

___ Elementary school

___ High school

___ Trade school

___ Community college

___ University

___ Professional school (medicine, optometry etc.)

___ Graduate school

2. How physically active, in work and leisure, would you say you have been in the last month?

(Mark one)

___ Very active

___ Active

___ Somewhat active

___ Inactive

3. Do you ever use a walker or cane to get around? __________________ (yes/no)

4. How would you say your health is these days? (Circle one)

1. Very good
2. Pretty good
3. Not too good
4. Poor
5. Very poor
6. Don't know

5. For your age, would you say in general your health is: (Circle one)

1. Excellent
2. Good
3. Fair
4. Poor
5. Bad
6. Don't know

6. During the past 12 months, have you had a fall where you actually hit the ground?
___________________ (yes/no)

7. How would you describe your usual ability to remember things? Are you: (Mark one)

___ Able to remember most things

___ Somewhat forgetful

___ Very forgetful

___ Unable to remember anything at all

8. How would you describe your usual ability to think and solve day to day problems? Are you: (Mark one)

___ Able to think clearly and solve problems

___ Having a little difficulty

___ Having some difficulty

___ Having a great deal of difficulty

___ Unable to think or solve problems

9. Has a health professional diagnosed you with any of the following long-term conditions? (Mark all that apply)

___ Asthma

___ Chronic Obstructive Pulmonary Disease

___ Heart disease

___ High blood pressure

___ Peripheral vascular disease

___ Diabetes

___ Cancer

___ Stroke

___ Alzheimer's disease

___ Epilepsy or seizure disorder

___ Arthritis or rheumatism

___ Neck or back problems excluding arthritis

___ Any other long-term condition (please specify)

____

10. In the past month have you taken any of the following medications? (Check all that apply).

___Pain relievers (e.g. tylenol, ibuprofen)

___ Codeine, demerol, or morphine

___ Tranquilizers (e.g. valium)

___ Diet pills

___ Anti-depressants

___ Cough or cold remedies

___ Allergy medicine (such as Sinutab)

___ Asthma medications (including puffers)

___ Medications for the heart

___ Medicine for high blood pressure

___ Diuretics or water pills

___ Insulin

___ Pills to control diabetes

___ Sleeping pills

___ Any other medications (specify)

___ No medications taken

APPENDIX 5: Screening Questionnaire

LAST NAME: ____________________ FIRST NAME: ____________________

ADDRESS:

____

____

PHONE NUMBER: ____________________ □ Female □ Male

DATE OF BIRTH: _____/______/_______ AGE: _____

DD MM YYYY

SELECTON CRITERIA:

1. Are you 65 years of age or older? Yes No

2. Do you have any problems with your ankle joints that might limit your ability to do ankle exercises? Yes No

3. Do you have a condition of your heart that is considered unstable? Yes No

4. Have you ever had a stroke? Yes No

If yes, explain what the effects are now?

____

____

____

____

5. Do you have any kind of condition that affects your movement abilities,

or your nerves and muscles?

Examples would include MS, Parkinson's. Yes
No

6. Do you have extreme difficulties holding things in your hands? Yes
No

7. Is there any other reason why you should not do physical Yes No

Activity? ________________________________

8. For how much longer will you be attending the program at Riverview?

____

(At least 6 weeks will be required for the study)

Is this person qualified to participate? Yes No

Date of first appointment:

APPENDIX 6: Sample size calculations

	Possible difference between means	Possible Standard Deviation	Minimum sample size
1.	**10**	**10**	**8**
2.	20	10	2
3.	30	10	1
4.	10	20	32
5.	**20**	**20**	**8**
6.	30	20	4
7.	10	30	71
8.	20	30	18
9.	**30**	**30**	**8**
10.	20	40	32
11.	30	40	14
12.	40	40	8

APPENDIX 7: The coefficient of variation values from the reliability pilot study

	Strength Training	Power Training
Dorsiflexion	Average velocity: 3.6 Peak velocity: 8.1 Range of motion : 2.4 Peak Acceleration : 21.3	Average velocity: 4.7 Peak velocity: 5.9 Range of motion : 2.3 Peak Acceleration : 25.9
Plantar flexion	Average velocity: 3.9 Peak velocity: 11.5 Range of motion : 2.6 Peak Acceleration : 35.6	Average velocity: 8.5 Peak velocity: 5.0 Range of motion : 5.8 Peak Acceleration : 11.7