ACKNOWLEDGEMENT

Physical activity and public health have always aroused curiosity in me, especially the meaningfulness of physical functioning and being able to be independent in daily living. When I got the chance to do my master project on gait and lower extremity strength in elderly I had to seize the opportunity. Through this process I have learned more about functioning throughout life, how to conduct a research project, and about statistic.

This would not have been possible if it was not for the participants of Generation 100. I would therefore like to thank the participants who voluntary participated and made this study conceivable. I would also like to thank my supervisors Professor Beatrix Vereijken and Per Bendik Wik for constructive feedbacks, for guiding me in the right direction, and for helping me with the equipment. I would also like to thank Ole Petter Norvang for countless phone calls made to Findland, in order to achieve optimal functioning of the leg press device. Thank you, Professor Thorlene Egerton, for valuable help with processing and analyzing the leg press data. Thank you, Espen Alexander F. Ihlen for making the Matlab script that made processing of leg press data easier. I would also like to thank Pernille Thingstad for helping me with the processing of gait data. You all made my day brighter with your smiles, humor, and your valuable knowledge aided me greately.

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Trondheim, May 2013
Ane Horten Flyen

ABSTRACT

Background: Gait speed has been strongly associated with functioning and also found to be a global index of functioning in elderly. Similarly, low general muscle strength has been associated with physical inactivity and functional impairment.

Aim: The aim of this study was to investigate whether there is an association between gait speed and lower extremity strength in elderly.

Design: This was a cross-sectional study.

Methods: 489 community-dwelling women and men (71.5 ± 5 yrs) filled out a questionnaire for background information, and were tested for gait speed and lower extremity strength. Gait speed was measured while participants walked in their preferred and fast gait speed on an electronic GaitRite walking mat. Lower extremity strength was tested with the Sit-to-stand performance test and leg press.

Results: Significant, low to strong, positive associations were found between both gait speed levels and the Sit-to-stand parameters in both genders ($p < 0.0005$). Fast gait speed was strongly associated with peak V in both women and men ($p < 0.0005$). There was found low to moderate associations between gait in both speed levels and leg press parameters in both genders ($p < 0.0005$). Strong associations were also found between gait speed and step length in both speed levels ($p <0.0005$) and between peak force (F) and peak rate of force development (RFD) in leg press in both genders ($p < 0.0005$).

Conclusion: Gait speed is associated with lower extremity strength in elderly, with increase in gait speed associated with increase in lower extremity strength. When gait speed increases, step length and cadence increases as well. Men walked faster and had stronger lower extremity strength than women. Future studies should investigate the direction of the association between gait speed and lower extremity strength through a prospective study, to see whether it is possible to maintain good function in gait by conduct lower extremity strength training or if it is more effective to focus on gait speed to maintain good lower extremity strength.

Key Words: Gait speed, step length, cadence, lower extremity strength, functional strength, isometric strength, leg strength, leg press, sit-to-stand test and elderly.

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1.0 INTRODUCTION

As the demographic development in Norway, along with the rest of the world, demonstrates an increase of the elderly population, a number of different challenges rise with it. A growing elderly population and a decreasing occupational participation will lead to an increasing need for care services (Helsedirektoratet, 2009). One way to approach this challenge is to focus on physical functioning, how to maintain good health and postpone hospitalization in this group as long as possible. Health is, among others, influenced by the level of physical functioning (Studenski et al., 2003), which can be sustained or improved by physical training (Capodaglio, Edda, Facioli, & Saibene, 2007; Mian, Baltzopoulos, Minetti, & Narici, 2007). Health and physical functioning are also associated with mobility, physical movement and gait (Studenski et al., 2003). According to Studenski et al. (2003), gait speed in particular has been shown to be a strong predictor of decline in both functional status and global health.

1.1 Age-related Changes in Gait

The human body changes with age and these changes may subsequently affect gait. Changes may occur in body composition (Beavers et al., 2013), lateral balance, step width, energetic cost (Dean, Alexander, & Kuo, 2007), gait speed, and stride length (Samson et al., 2001). Additionally, cognitive impairment, reductions in muscle strength, proprioception and reaction time, and changes in sensory systems are also related to age and gait in general (Rochester, Howe , Skelton, & Ballonger, 2012). With respect to body composition, an increase in thigh intramuscular fat, together with a decreasing total muscle area, has been found to be an important predictor of a decline in gait speed (Beavers et al., 2013). This also implies that a high or increasing fat infiltration in muscles may lead to a loss of mobility with age. According to Dean et al. (2007) lateral balance, step width and energetic costs are affected by age. In their study of eight young adults (age < 30 yrs) and ten older adults (age > 65 yrs), they found that older adults walk with wider steps, have a larger variability in step length and larger energetic cost than younger adults in habitual gait. Lateral balance was also affected by these age-related changes, and compensating for a poorer lateral balance may explain most of the higher energetic costs during gait. No significant differences in step length and step frequencies were found (Dean et al., 2007). In contrast, Samson et al. (2001) examined 118 women and 121 men within the age range 19-90 years, and found that stride length decreases with increasing age.

With ageing, the risk of falling increases, and falls often lead to injury, loss of independence, illness and death (Rochester et al., 2012). Most of the falls in elderly happen when walking on floor or uneven, bumpy ground (Berg, Alessio, Mills, & ChenTong, 1997). A higher variability in step width is associated with a history of falls (Brach, Berlin, VanSwearingen, Newman, & Studenski, 2005; Hausdorff, Rios, & Edelberg, 2001). Hausdorff et al. (2001) found that the variability in gait was significantly increased in fallers compared to non-fallers. Additionally, gait variability was found to be predictive of future falls and elderly with large gait variability were more likely to fall sooner than those with a smaller gait variability. A decreasing ability to sustain balance was also associated with an increased risk of falling and a higher rate of cognitive decline (Rochester et al., 2012). Furthermore, Rochester et al. (2012) found that interventions focusing on balance training have a positive effect on decreasing the risk of falling among elderly with a history of falls. According to previous research, the maintenance of good gait function seems to be important relative to the risk of falls (Brach et al., 2005; Rochester et al., 2012).

Gait Speed

Samson et al. (2001) found that gait speed decreases with increasing age in healthy elderly. Their findings showed no differences between men and women in percentage decline, but in absolute values, women walked slower than men regardless of age. In several studies, a slow gait speed alone has been related to an increasing risk of adverse events, such as an increasing need for caregivers, fractures, institutionalization and mortality (Lyyra, Leskinen, & Heikkinen, 2005; Montero-Odasso et al., 2005; Studenski et al., 2003). Elderly with a slow gait speed had more than three times higher risk of mortality than elderly who had a normal gait speed and more than four times higher risk than those with the highest gait speed (Lyyra et al., 2005). A slow gait speed is also associated with increased risk of cognitive impairment (Bramell-Risberg, Jarnlo, & Elmståhl, 2012) and fatal falls (Ratanen, 2003). In contrast, an increase in habitual gait speed, that results in transition to a higher level of ambulation, has been shown to result in better function and quality of life (Schmid et al., 2007), and a predictor of reduced mortality risk among elderly(Hardy, Perera, Roumani, Chandler, & Studenski, 2007). Studenski et al. (2003) performed a study on gait speed and physical functioning. They found that while those who walked slowest had a69 % incidence of new difficulties in personal care over one year, only 12 % incidence of such new difficulties developed among those who walked the fastest. Because of the many variables that gait speed correlates with, and can predict, gait speed is often used as a global index of functional level in elderly (Studenski et al., 2003).

Gait speed is a practical index for functional level, as gait speed measurements are easy to perform, both clinically and non-clinically (Montero-Odasso et al., 2005). Gait speed alone may provide an important foundation for diagnosis and initiating medical or physical interventions (Studenski et al., 2003). As gait speed is one of many determinant for gait (Samson et al., 2001), there may also exist determinants for gait speed, such as various lower extremity strength.

1.2 Aging and Muscle Strength

Previous research has found that sarcopenia, the degenerative loss of motor neurons, skeletal muscle mass and muscle strength as a result of normal aging, is an important determinant for physical functioning, and is significantly associated with functional impairment and disabilities (I. Janssen, Heymsfield, & Ross, 2002; Reid, Naumova, Carabello, Phillips, & Fielding, 2008). With increasing age, the human body's muscles fibers change, which in turn affects muscle strength and functioning (Macaluso & De Vito, 2004). With age, there is selective atrophy of fast-twitch muscle fibers and reduced tendon stiffness, along with neural changes, such as lower activation of the agonist muscles and a higher coactivation of the antagonist muscles. The selective atrophy of fast-twitch muscle fibers seems to result from the progressive loss of motoneurons in the spinal cord. Parallel to the selective atrophy of fast-twitch muscle fibers, a reinnervation of close-lying slow-twitch muscle fibers often occurs (Macaluso & De Vito, 2004). After passing the age of 70, this muscle atrophy seems to speed up (Danneskiold-Samsøe et al., 1984). It was also found that the tension and shortening speed in older muscle fibers are lower compared to younger muscle fibers (Macaluso & De Vito, 2004).

In addition, low general muscle strength is associated with older age, and is independently associated with a higher risk of mortality (Ratanen, 2003). It is also associated with lower body weight (Era et al., 1994 I: Ratanen 2003), presence of chronic diseases (Ratanen, 2003), physical inactivity (Ratanen, Era, Hekkinen, 1997 I: Ratanen, 2003), and lower education (Ratanen, 2003). According to Lyyra et al. (2005) those who have low general muscle strength have more than two times higher risk of mortality than those who have normal general muscle strength. Furthermore, those with low general muscle strength have more than three times higher risk of mortality than those who have the highest general muscle strength. High general leg strength is associated with a slower rate of mobility decline (Lyyra et al., 2005).

Lower Extremity Strength

An increase in lower extremity muscle strength was found to be associated with increased mobility skills (Chandler, Duncan, Kochersberger, & Studenski, 1998), which makes lower extremity strength an important determinant for mobility-based functional activities (Samuel & Rowe, 2009). In a study of lower extremity muscle strength, postural control and risk of falls, it was found that ankle dorsiflexion and hip extension force in fallers were lower than in non-fallers (Daubney & Culham, 1999). Many independent elderly modify their activities in daily living to decrease the gap between the physical environments requirements and their personal assumptions (Marko, Neville, Prince, & Ploutz-Snyder, 2012). Marko et al. (2012) did a study of isometric lower extremity muscle strength and modification in daily activities among community-dwelling elderly, and found that lower extremity strength was significantly associated with modifications in activities. They also found that modification of activities strongly predicts future disabilities in mobility, which means that when elderly starts to use other strategies, as adjusting the physical environment to their own abilities, it is likely that their lower extremity strength is getting weaker. This can also give information about future mobility function.

Lower extremity muscle strength is a term used broadly and can be estimated in several different ways. Isometric contractions are frequently used as a direct measurement of muscle strength, and are weight-bearing tests were the muscles length are constant (Chandler et al., 1998; Marko et al., 2012; Schaubert & Bohannon, 2005). Isometric tests are also known as static tests, and one example of such test was done by Schaubert and Bohannon (2005), as they measured knee extension strength were the knee angle is constant as done. They used a hand-held dynamometer, which the participants were told to push as hard as possible, attempting to straighten their knees. Another approach to estimate lower extremity strength is using functional tasks that require dynamic contractions, which also has been frequently used in previous studies (Chandler et al., 1998; Guralnik et al., 2000; Schaubert & Bohannon, 2005). Tests such as the 6 minute walk test (Camarri, Eastwood, Cecin, Thompson, & Jenkins, 2006), timed up-and-go test (Schaubert & Bohannon, 2005)and sit-to-stand performance test (Guralnik et al., 2000; Schurr, Sherrington, Wallbank, Pamphlett, & Olivetti, 2012) are all examples of such functional tasks used to estimate lower extremity. These functional tests are easy to perform and well established in both research and clinical settings.

1.3 The Present Study

The purpose of this study was to investigate whether there is an association between gait speed and lower extremity muscle strength in elderly. Gait speed was measured while participants walked at preferred and fast tempo. Lower extremity strength was measured by an isometric strength test and a functional test. For isometric leg strength, a leg press exercise was used, and for the functional strength the Sit-to-stand performance test was used. Whether there is a relationship between gait speed and lower extremity strength is important to explore because it can illuminate whether the level of lower extremity strength have an influence on gait speed, and subsequently the functional level in elderly.

2.0 METHODS

2.1 Study Design

A population-based, cross-sectional design was used to investigate whether there was a relationship between lower extremity muscle strength and gait speed in older elderly. Lower extremity muscle strength was assessed using a bilateral leg press exercise (isometric leg strength) and the Sit-to-stand performance test (functional muscle strength).

Data collection was done through a larger project, *Generation 100*, a prospective clinical research project that studies the relationship between physical exercise, morbidity and mortality in elderly. All men and women living in Trondheim municipality, born in the period from 1938 to 1942, were invited to participate. Data collected in Generation 100 started in August 2012 and contains several clinical tests, lab measurements, and self-reported questionnaires.

2.2 Participants

All participants in Generation 100 had to be between 69 and 74 years old, and be able to walk continuously for at least 1000 meters. Walking aids were allowed. Participants with diseases or disabilities that prevented them from training or participating in Generation 100 were excluded. Other exclusion criteria were uncontrolled hypertension, symptomatic cardiac valve defects, hypertrophic cardiomyopathy, unstable angina, pulmonary hypertension, heart failure, severe cardiac arrhythmias and cancer that would make participation impossible or exercise dissuaded by their general practitioner. Participants were also excluded if results during testing indicated that participation was not safe, and if they at the same time participated in another study not compatible with Generation 100.

For the current study, data collected between September 1th and October 31th were selected for analyses. These nine weeks of data collection contained gait speed data of 485 participants, sit-to-stand data from 485 participants and 467 participants from the leg press exercise. For 480 of these participants, background data was available as well through a self-reported questionnaire. After merging all data, total sample size came to 489 subjects that were used in further analysis, 258 women and 229 men (Table 1). An independent-samples t-test on height and weight showed that men were significantly taller, $t(464) = -26.487$, $p < 0.0005$, and weighed significantly more than women, $t(464) = -13.592$, $p < 0.0005$.

Table 1: Participant characteristics and results from independent- samples t-tests

	Women		Men			
	N	Mean (SD)	N	Mean (SD)	t	p
Age	246	71.59 (1.41)	220	71.41 (1.43)	1.372	0.171
Height (m)	251	165.08 (4.86)	215	178.20 (5.84)	-26.487	< 0.0005
Weight (kg)	257	68.64 (10.85)	228	82.28 (11.22)	-13.592	< 0.0005

2.3 Procedure

All men and women in the appropriate age group were sent an invitation via the postal system. This invitation contained information about the purpose of the study, who could participate and what type of tests they would go through. They also received Questionnaire 1 with questions regarding background information, civil status, education, physical activity and general health. Those who wanted to participate filled out the questionnaire and sent it back. They were then contacted by Generation 100 and given a date for testing.

On the day of testing the subjects had to fast for at least 2 hours before start. At the first of three test stations they received three new questionnaires about physical activity, general health and nutrition, which they were asked to fill out during the day. At the same test station, tests were performed with respect to blood samples, blood pressure, heart rate at rest, body composition and spirometry. After test station 1, they had at least 30 minutes break in which they were recommended to eat, rest and fill out the questionnaires. They were not allowed to drink tea or coffee. Test station 2 included measurements of gait, grip strength, leg strength, sit-to-stand performance test, VO2 max test and an additional blood sample. Then, at the last test station the self-reported questionnaires were handed in, and the subjects were randomized into one of three groups; high intensity exercise group, moderate intensity exercise group and control group.

For the current study, data from Questionnaire 1, and gait speed data, leg strength data and sit-to-stand data from test station 2 were used for further analyses.

2.4 Outcome Measures

Gait Speed

Gait speed was measured by having the participants walk on an electronic GaitRite walking mat. This pressurized mat was 6.46 m long in total, with the middle 5.49 m being the active measurement area. The total distance the participants walked was 8.7 m, so that speeding up and slowing down occurred before and after walking on the mat. All participants were asked to wear comfortable shoes, such as training shoes, without heels. They walked four times back and forth on the mat, resulting in eight trials. For the first two trials, they were instructed to walk in their preferred gait speed, the second two trials to walk slowly, as if they were waiting for somebody. Next, they were asked to walk as fast as they could without running. For the last two trials, they were asked to walk in their preferred gait speed and count numbers at the same time, starting at 80 or 100 and subtracting three and three at the time. For the current study, only the trials at preferred gait speed and fast gait speed were used for further analyses.

Leg Press Parameters

For measuring bilateral leg strength, the FCM 5540 Leg Press Rehab Standard was used, developed by Helsinki University of Research (HUR). This device was specifically developed for elderly people, making it easier to get in and out of, and allowing a more open angle in the hip, knees and ankles. There were two power cells, one for each foot, between the footplates and the main part of the device. The applied force on the footplates by the participants was measured with 50 Hz over a period of 5 seconds.

The participants were instructed to sit with their arms across their chest, with each arm at the opposite shoulder. Their feet were placed one on each footplate, with their heels against the lower edge. The back of the seat was adjusted to make the angle of the knees 110 degrees. A pillow was placed behind the back for participants with shorter legs than the adjustable back of the seat could account for. Participants were instructed to be explosive when they pushed, hold for approximately three seconds, and then quickly release the power. They received instructions throughout the testing- when to start and when to stop. They were also instructed to push with both legs at the same time, totally 6 times. During the first three pushes left leg strength was measured and the right leg strength during the last three pushes. This order was the same for all participants, but they were not informed that strength was measured only one leg at the time.

In the further analyses Peak Force (peak F (kg)) and Peak of Rate of Force Development (peak RFD (kg/s)) were used. When processing the leg press parameters the highest peak F and peak RFD were selected across the three trials for each leg and then summarized across both legs. Trials were excluded when starting push was above 5 kg, when the force continued to rise through to the end without reaching a plateau, and when the participants were "pumping", resulting in multiple force peaks during the trial. Furthermore, peak RD was discarded when it occurred after peak F was achieved. An example of an included trial from the leg press exercise is shown in Figure 1. The test subject had no starting point problem as the force at start is below 5 kg, and the peak RFD occurs early in the trial.

Figure 1: Example of a good trial

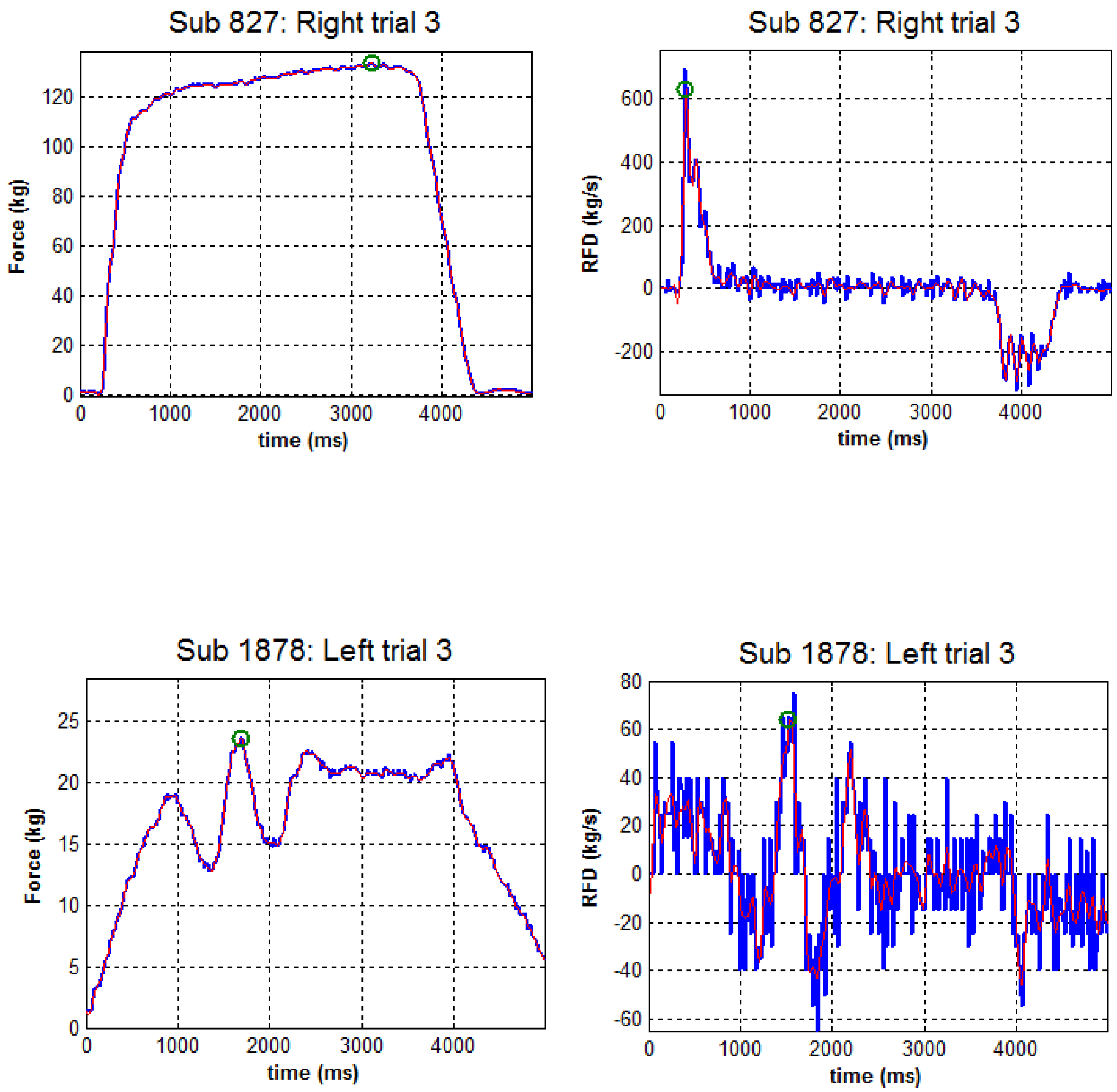
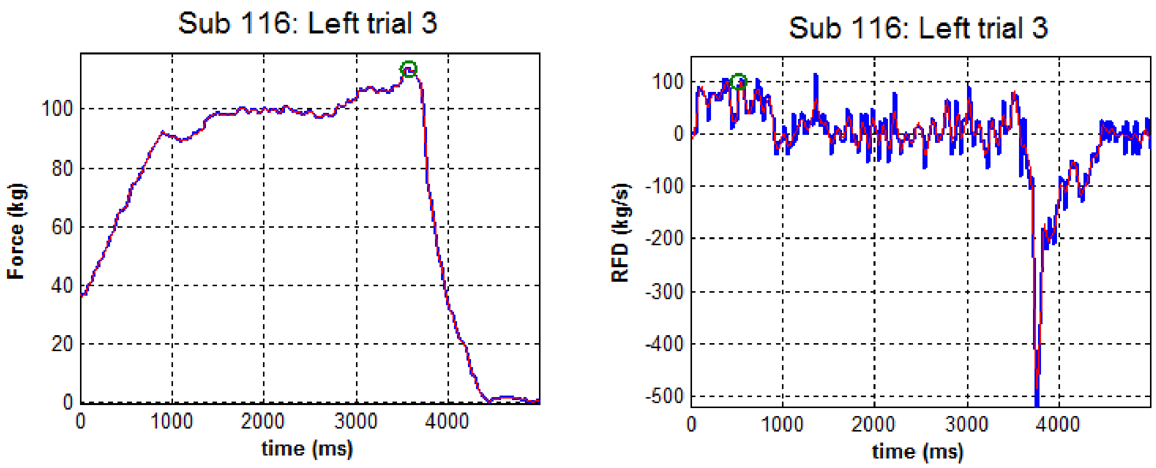


Figure 3 shows a trial that was not approved because the participant had started to push before the trial started.

Figure 3: Example of a not approved trial



Sit-to-Stand Parameters

The Sit-to-stand performance test is a concentric and more functional strength test than the isometric leg press. It is designed to measure the speed a person achieves when getting up from a chair to a standing position. When running this test, the Muscle-Lab software connected to a linear encoder was used. The participants were sitting on a regular chair without armrests, but with backrest. This chair had a standard seat height of 45 cm and was placed against the wall to prevent the chair from slipping. They were instructed to have their arms crossed and both feet placed on the floor. No counter movement was accepted, trials were approved only when both feet were touching the floor at all time during testing.

Variables measured were the distance of movement (cm), average velocity (average V (m/s)), peak velocity (peak V (m/s)), total time used to accomplish each trial (s) and time to peak velocity (s). In the current study, only average V and peak V were used, as these values combine information about the distance of movement and total time used. Each participant completed five trials consisting of one chair-rise each. The first trial was considered a test trial for the participants to familiarize themselves with the test, the last four trials were used in subsequent analyses.

2.5 Statistical Analysis

All data were processed before running statistical analyses. Gait Speed data was processed using custom-ware GAITRITE38E before it was output to a Microsoft Excel 2010 file, while the data from Sit-to-stand Performance Test where output directly into Excel. The approvals of trials from the Leg Press Exercise Test were done by screening graphical depictions of peak F and peak RFD, generated by MatLab R2012b before the variables were output into Excel. Data from Questionnaire 1 was scanned directly into a SPSS file. All data were merged into a single SPSS file before further analyses were performed using SPSS Statistics 20.

In SPSS, the variables listed in Table 2 were calculated. For gait speed, the average of the two trials at each speed level was calculated. The same was done for step length and cadence as well. For leg press, the highest values for peak F and peak RFD per foot were selected before the mean of left and right foot was calculated. The mean of the last four trials in the Sit-to-stand test was also calculated and used in further analyses.

Table 2: List of Variables

Gait	Lower Extremity Strength	
Gait Parameters	**Leg Press Parameters**	**Sit-to-stand Parameters**
• Preferred Gait Speed • Fast Gait Speed • Step Length Preferred • Step Length Fast • Cadence Preferred • Cadence Fast	• Peak Force • Peak Rate of Force Development	• Average Velocity • Peak Velocity

Statistical analyses consisted of independent-samples t-tests, paired-samples t-tests , and correlation analysis using Pearson's correlation coefficient. To determine whether the correlations were low, moderate or high, the guidelines of Pallant (2007) were used (see Table 3). To check for confounders, partial correlations were calculated. It was decided not to scale gait- and lower extremity strength parameters to height as mainly paired-statistics were used.

Table 3: Guidelines for interpreting r-values

r = 0.1- 0.29	Low
r = 0.3- 0.49	Moderate
r = 0.5- 1.0	Strong

2.6 Ethics

All persons participated voluntarily, and signed an informed consent prior to any testing. They were at any time free to withdraw their consent and leave the project. This larger Generation 100 study was approved by the Regional Committee for Medical Research Ethics, Southern Norway (REK).

3.0 RESULTS

Of the 489 elderly that voluntary participated, there were one person that had missing data on gender information. In addition to this one, 258 women and 229 men had filled out questionnaire 1, and participated in the physical testing of gait and lower extremity strength. Women were slightly overrepresented. The participants had a mean age of 71.5 years (Table 1). One of the participants walked with a walking stick. Other than that, no walking aids were used among the participants.

First, descriptive statistics of the performance in each test were explored. Then, t-tests were done to investigate differences between genders. For gait parameters it was also investigated whether the participants actually did walk faster when they were asked to during the gait test. These test results for each parameter are presented below. The last part contains the investigation of the associations between the gait parameters and the lower extremity parameters. Pearson correlation coefficient, stratified for gender, was used. Partial correlation was used to control for variables that may affect the associations. Variables that were controlled for were height and weight.

3.1 Gait parameters

The participants mean walking speed was 1.32 m/s in preferred gait speed, with a range from 0.66 m/s to 1.94 m/s. In fast gait speed their mean speed was 1.9 m/s with a range from 0.65 m/s to 3.07 m/s. The participants mean step length in normal gait speed was 0.71 m (0.46-0.95), while the mean step length in fast gait speed was 0.84 m (0.44-1.09). The mean cadence in preferred gait speed was 111.6 steps per minute (80.1-145.2), while the mean cadence in fast gait speed was 136.3 steps per minute (88.3-184.1).

Differences between gait parameters in preferred and fast gait speed were investigated using paired-samples t-test. It was found that the participants walked significantly faster when they were asked to do so, than when they were asked to walk at their preferred gait speed, $t\ (484) = -56.090$, $p < 0.0005$. A paired-samples t-test on step length in preferred and fast gait speed, showed that the participants had significant larger step length in fast gait than in preferred gait $t\ (484) = -45.044$, $p < 0.0005$. It was also found that cadence in fast gait was significant higher than in preferred gait, $t\ (484) = -46.537$, $p < 0.0005$.

When investigating possible differences in gait parameters between women and men, independent-samples t-tests were used. It was found that men had significantly higher mean values in all variables except cadence in both preferred and fast gait (Table 4). In cadence in both preferred and fast gait speed women were had significantly higher values than men.

Table 4: Gait parameters for each gender and results of independent-samples t-tests

	Women (N=256)		**Men** (N=228)			
	Mean	SD	Mean	SD	t	p
Preferred Gait speed	130.118	20.339	134.194	20.4	-2.197	0.028
Fast gait speed	182.157	27.109	198.331	29.756	-6.257	< 0.0005
Step Length Preferred	67.494	6.633	74.665	7.956	-10.807	< 0.0005
Step Length Fast	78.211	8.409	89.592	9.125	-14.278	< 0.0005
Cadence Preferred	115.218	10.464	107.477	8.129	9.008	< 0.0005
Cadence Fast	139.521	12.533	132.718	13.184	5.817	< 0.0005

3.2 Lower Extremity Strength

Leg press Parameters

Preliminary to the analyses of leg press parameters, mean of the highest value of left and right leg was calculated. This was done for both peak F and peak RFD. The participants had a mean peak F of 91.9 kg with a range from 16.3 kg up to 218.8 kg. For peak RFD the mean was 293.4 kg/s, with a range from 36.8 kg/s up to 836.3 kg/s. An independent-samples t-test showed that men were significantly stronger than women (Table 5). It was also found that men had a significantly higher peak RFD than women.

Table 5: Leg Press parameters for each gender

	Woman (N=246)		**Men** (N=221)			
	Mean	SD	Mean	SD	t	p
Peak Force	69.380	22.689	116.976	33.934	-17.977	< 0.0005
Peak RFD	197.558	102.764	400.158	170.416	-15.733	< 0.0005

Sit-to-Stand Parameters

For the Sit-to-stand performance test the mean of the last four trials were calculated for both average velocity (V) and peak velocity (V). The participants had a mean velocity of 0.5 m/s. The slowest had a mean velocity of 0.2 m/s, and the fastest 1.0 m/s. For peak V, the participants had a mean velocity of 1.2 m/s. The lowest peak V value was 0.4 m/s and the highest 1.9 m/s. An independent t-test on average V showed that men were significantly faster than women (Table 6). It was also found that men had significantly higher peak V than women.

Table 6: Sit-to-stand parameters for each gender

	Women (N=257)		**Men** (N=228)			
	Mean	SD	Mean	SD	t	p
Average velocity	0.415	0.115	0.588	0.149	-14.395	< 0.0005
Peak velocity	0.949	0.199	1.243	0.205	-15.964	< 0.0005

3.3 The Association between Gait and Lower Extremity Strength

The relationship between gait and lower extremity strength was investigated using Pearson correlation coefficient. First the correlations within each test were explored. Then the correlations between the different parameters were investigated before possible effects of background variables on the correlations were inspected.

Gait Speed, Step Length and Cadence

A strong, positive correlation was found between preferred gait speed and fast gait speed, $r = 0.643$, $n = 485$, $p<0.0005$, and between fast gait speed and step length in fast gait, $r = 0.789$, $n = 485$, $p < 0.0005$. These correlations had an explained variance of 41.3 % and 62.3 %, respectively. Preferred gait speed and step length in preferred gait speed also had a strong, positive correlation, $r = 0.824$, $n = 485$, $p < 0.0005$, which gives an explained variance of 67.9 % between the two parameters. A low, or no significant correlation was found between cadence in both preferred and fast gait, and step length in fast gait, but a strong positive correlation was found between cadence in preferred gait and preferred gait speed, $r = 0.703$, $n = 485$, $p < 0.0005$. The correlations between gait speed and the other gait parameters are shown in table 7.

Table 7: Pearson correlation coefficients between gait speed and the other gait parameters*

All	Preferred Gait Speed	Fast Gait Speed
Step Length Preferred	0.824	0.671
Step Length Fast	0.534	0.789
Cadence Preferred	0.703	0.268
Cadence Fast	0.352	0.599

*p< 0.0005 for all values

Leg Press and Sit-to-Stand Performance Test

Within the leg press variables it was found a strong, positive correlation between peak F and peak RFD, r = 0.745, n = 467, p < 0.0005. A positive correlation was also found between average V and peak V for sit-to stand parameters, r= 0.890, n = 485, p < 0.0005. It was found significant correlations between all leg press parameters and sit-to-stand parameters (Table 9). In women, the correlations between all these parameters were found to be moderately, positive. For example, the relationship between average V in the Sit-to-stand test and peak F from leg press was found to have an explained variance of 13.1 %, r = 0.362, n = 245 p < 0.0005. The correlations between average V and peak RFD in men were found to be positive, but low with an explained variance of only 7.0 %. A similar low correlation coefficient was found between average V and peak F (8.8 %), while moderate correlations were found between peak V and peak F (11.1 %), and between peak V and peak RFD (9.8 %) in men.

Table 9: Pearson product-moment coefficient between the lower extremity strength variables, stratified for gender*

	Women		Men	
	Average V	Peak V	Average V	Peak V
Peak F	0.362	0.332	0.297	0.333
Peak RFD	0.351	0.349	0.264	0.313

*p < 0.0005 for all values

Gait, Gait Speed and Lower Extremity Strength

There were found significant, positive correlations between gait parameters and lower extremity strength parameters (Table 10). Gait speed and step length in both preferred and fast gait speed were found to have moderate to high, positive correlations with the Sit-to-stand parameters in both genders. With leg press, gait speed and step length were found to have low to moderate, positive correlations in both women and men. For example, between fast gait speed and peak F it was found a significant, but low correlation in men, p = 0.227, n = 219, p = 0.001. In women, a significant, moderate correlation was found between the same parameters, r = 0.351, n = 244, p < 0.0005. The correlations between cadence in fast speed and the leg press parameters in women were found to be significant, but low. No significant correlations were found between cadence in preferred speed and the leg press parameters in women. In men there were no significant correlations between cadence at both speed levels and the leg press parameters. Between cadence and sit-to-stand parameters, low to moderate, positive correlations were found in both genders.

Table 10: Pearson correlation coefficient between gait and lower extremity strength

Women	**Preferred Gait Speed**	**Fast Gait Speed**	**Step Length Preferred**	**Step Length Fast**	**Cadence Preferred**	**Cadence Fast**
Average V	0.351	0.458	0.401	0.434	0.191	0.242
Peak V	0.408	0.525	0.427	0.481	0.265	0.308
Peak F	0.230	0.351	0.296	0.342	(0.098*)	0.178
Peak RFD	0.156	0.267	0.209	0.223	(0.060*)	0.171
Men						
Average V	0.344	0.407	0.339	0.352	0.228	0.262
Peak V	0.453	0.510	0.434	0.438	0.316	0.323
Peak F	0.243	0.227	0.278	0.252	(0.118*)	(0.093*)
Peak RFD	0.257	0.212	0.299	0.207	(0.115*)	(0.124*)

* Not significant (p > 0.05)

Partial correlations were used to control for weight and height. When the data was stratified for gender, no confounding variables were found. When using the whole data set, it was found that weight had no effect on the correlations. For example, there was found a strong, positive, partial correlation between fast gait speed and peak V, when controlling for height, r = 0.575, n = 480, p < 0.0005, with fast gait speed associated with higher peak V in the Sit-to-stand performance test. A check of the basic correlation coefficient (r = 0,564) suggested that controlling for height had no effect on the strength of the association between these two variables. On the other hand, there was found a moderate, positive, partial correlation between step length in preferred speed and peak F, $r = 0.298$, $n = 441$, $p < 0.0005$, when controlling for height. A check of the basic correlation coefficient ($r = 0.488$) suggested that controlling for height did have an effect on the strength of the association between step length in preferred gait speed and peak F. It was also found a moderate, positive, partial correlation between peak F and peak V, $r = 0.444$, $n = 443$, $p < 0.0005$, when controlling for height. An inspection of the basic correlation coefficient ($r = 0.581$) suggested that controlling for height had an effect on the strength of the association between these two variables. No effects on the strength of the associations were found when controlling for weight.

4.0 DISCUSSION

The aim of this study was to investigate whether there was an association between gait speed and lower extremity strength in elderly. Gait speed was measured while participants walked in preferred and fast speed, while lower extremity strength was measured by the Sit-to-stand performance test and leg press. The main results showed that there were significant, positive correlations between gait speed and lower extremity strength, in both preferred and fast gait speed, but these correlations were largely low to moderate. Only the correlation between fast gait speed and peak V was found to be strong.

4.1 Findings

Lower Extremity Strength and functioning

The current study found a significantly, strong, positive correlation between peak F and peak RFD from the leg press test. This indicates that when testing lower extremity strength by using leg press, we can choose to measure only one of these variables since they will provide similar outcomes. The results in the current study also showed significant, positive correlations between all leg press parameters and the Sit-to-stand parameters, which matches results found in previous studies. Chandler et al. (1998) did a study on lower extremity strength and chair-rise performance, and found significant, positive associations between these two variables. They also found significant, positive associations between lower extremity strength and physical functioning. This indicates that improvements in lower extremity strength are associated with improvements in mobility and in physical functioning. Additionally, they found that strength gain seemed to have a larger effect on sit-to-stand performance test in the lower functioning group as compared to the higher functioning group. The results in the current study pointed to possible differences in the strength of the correlations between the two tests of lower extremity strength and the gait parameters. However, there were no great variations in the performances achieved by the participants. The variation in performance may have been larger if the participants had included older and frailer persons.

Gait, Gait Speed and Lower Extremity Strength

The current study found that men walked significantly faster in both speed levels than women. This match the result found in the Samson et al. (2001) study on 118 women and 121 men, aged 19- 90 years old. They found that the percent-wise decrease in gait speed and stride length was larger among women than men, and that women had lower absolute values at all ages than men (Samson et al., 2001). This may be due to women having a generally lower muscle mass and strength than men (I. Janssen et al., 2002). Furthermore, Callisaya, Blizzard, Schmidt, McGinley, and Srikanth (2010) investigated the relationship between preferred gait speed and age in elderly aged 60-86 years old. They found a significant, negative association between these two parameters, were gait speed decreases with ageing. The findings mentioned above may be explained by muscle strength and balance impairments (Ratanen, 2003). Ratanen (2003) conducted a study on muscle strength and gait. They found that increased muscle strength were associated with decreased risk of developing limitations in walking, but only among people with balance impairments, not among those who had a good balance. Callisaya et al. (2010) also found significant, negative associations between these gait speed and gait variability in both men and women. Their results showed that as gait speed increased the variability in step length decreased. The current study did not investigate gait variability, but found significant, low to moderate, positive associations between gait speed and step length in both genders. It was also shown that cadence had a strong, positive association only with preferred gait, which was not surprising when cadence is an estimate of number of steps and ambulation time during gait. Compared to mentioned researches, the current study by design included a homogeneous group of elderly, but in future research a more diverse and heterogeneous group could be of interest to explore. No such associations were found in the current study, probably due to the homogeneity in age, gait speed and lower extremity strength of the sample population.

The findings in the current study of significant correlations between gait speed parameters and leg strength is consistent with an earlier study of Chandler et al. (1998). They did a prospective controlled clinical trial of 100 elderly. They found a significant, positive association between gait speed and lower extremity strength, but they included functionally impaired community-dwelling elderly. Other results may therefore be expected among the participants in the current study. Another study found that gait speed was significantly associated with lower extremity strength as well, but only in men, which may suggest that there are gender differences in strategies of how to cope with age-related changes in functioning (Sayers, Guralnik, Thombs, & Fielding, 2005). Such gender differences was not found in the current study and may be due to the participants being a rather homogeneous group of well-functioning elderly, living independently in their private homes and being close in age. In the Sayers et al. (2005) study, the participants were community-dwelling elderly from 75 to 90 years old. This may cause larger differences in muscle strength because of more advanced sarcopenia and the increasing acceleration of selective atrophy of fast-twitch muscle fibers after passing 70 years (Danneskiold-Samsøe et al., 1984). As mentioned above, women generally have lower muscle mass and strength than men (I. Janssen et al., 2002), gender differences may become more visible when sample population becomes older than the participants in the current study.

4.2 Methodical considerations

Participants

The current study included a total of 489 participants, and obtained several parameters that expressed different aspect and measures of gait and lower extremity strength, which are and strengths of this study. The participants mean age was 71.5 year old, which was relatively young. According to Danneskiold-Samsøe et al. (1984), the acceleration of selective atrophy of fast-twitch muscle fibers increases when passing the age of 70. Due to these previous findings it would have been expected that the participants in the current study would show a decline in gait speed and lower extremity strength compared to the younger population. At the same time it is important to remember that the participants mean age was only one year older than 71, which may not be enough to capture any generally functional decline.

Gait

In elderly, a preferred gait speed over 1.3 m/s has been categorized as extremely fit (Studenski et al., 2003). The participants in the current study walked 1.3 m/s in preferred gait speed, and only one of the participants needed a walking stick to cope with daily functioning. Furthermore, about 1/3 of all elderly that was invited to participate in the bigger study Generation 100 enrolled in the study, indicating the possibility of selection bias. While those who are frail, or do not enjoy exercise probably do not participate in such research, it was probably a vigorous group of elderly who participated in the current study. It might also be that the participants exerted extra effort while being tested, thereby performing better during the tests than they might do in everyday activities. This as a result of being observed and being encouraged to perform their absolute best during testing. It is also likely to believe that the positive attention and the feeling of contribute with something important also affected the participants performance.

Leg Press

The device used in the present study to study isometric leg press was the HUR leg press rehab device. This device was specially adapted for elderly people by the reclined position which allows a more open angle in the hip, knees and ankles. The HUR leg press rehab device was also easier to get in and out of. The HUR leg press device has not been used in research before, and has not been validated.

The protocol for this test included instructing the participants to push as hard as they could, with both legs simultaneously against the force plates. During the three first trials, only the left leg was measured, and then the right leg was measured during the next three trials. It was found that the right leg was significant stronger than the left leg. This result might be due to a steep learning curve that first was taken into account after the current group of elderly was tested. Because right leg had higher values for peak F and peak RFD than left leg, and the testing order always being left first, then right, the best left and best right were averaged to a single peak F and peak RFD for each participant. Another aspect is the possible effect of leg dominance on lower extremity muscle strength. Hunter, Thompson, and Adams (2000) did a study of 217 women (20-89 yrs) were they investigated the effect of dominant and non-dominant leg on maximal voluntary strength (MVC) in knee extensors and plantar flexors. They found that the dominant leg had a significantly higher MVC than the non-dominant leg. Because the participants in the current study performed with both legs, but had only one leg measured at the time, it is natural to believe that they did not reach their absolute maximum voluntary peak force in either left or right leg. This comes as a result of the effect of both the learning process and having a dominant leg, which subsequently may affected mean peak F and peak RFD. Although, Hunter et al. (2000) found significant differences between dominant and non-dominant leg, the effect of leg dominance was relatively small. In addition, the HUR leg press rehab device did not cope well with the full range of body sizes of the participants. The angle of the knees should have been 110 degrees for all participants before start, but some participants had shorter or longer legs than what could be adjusted for. For those with too short legs, a pillow was placed behind the back to compensate for this, but with the pillow some of the participants reached full knee extension likely without achieving peak force. Those with possibly too long or too short legs were not excluded in the current study, which may have given lower peak F and peak RFD than they actually could achieve. Despite these weaknesses in the HUR leg press rehab device, we found significant, low to moderate, positive correlations between the leg press parameters and the Sit-to-stand parameters. This strengthens the validity of the tests and suggests that the leg press parameters can be trusted, but further research is needed to validate the HUR leg press rehab device against other tests.

Sit-to-Stand Performance Test

The Sit-to-stand performance test has frequently been used in previous studies, but usually as the 5-times-sit-to-stand test were time taken to accomplish five chair-rises at once are measured (Schaubert & Bohannon, 2005; Whitney et al., 2005). In the current study, the Sit-to-stand performance test was conducted as five individual chair-rises, yielding five trials. By using a linear encoder instead of a manual stop-watch, more precise measures could be collected not just time taken to rise, but also average velocity and peak velocity during the chair rise. In contrast to the Sit-to-stand performance test the 5-times-sit-to-stand test measures all five chair-rises included the time the participants use to sit down, and start over again. The Sit-to-stand performance test measures only each chair-rise, which probably also makes it more precise. Nevertheless, it would be interesting to investigate whether the 5-times-sit-to-stand test or the single sit-to-stand test yields the best estimate of lower extremity strength. In further analyses of the current data it would also be interesting to explore the variability between the five trials, and investigate whether this has a relationship with gait speed or lower extremity strength.

Finally, previous research has indicated that the height of the chair seat affects the ability to conduct the Sit-to-stand performance test (W. G. M. Janssen, Bussmann, & Stam, 2002). A higher seat causes lower movement in knees and hip during a chair-rise, because the knee angels at start are more open than using a lower chair seat. A low chair seat causes greater movement because of lower knee angles at start, which results in an increasing need for producing movement compared to a high chair seat. Repositioning of the feet is also a frequently used strategy to increase the knee angels and lower the movement in knees and hip. The participants in the current study had to accomplish the Sit-to-stand performance test using the same chair, despite differences in leg length. This may have affected the results because differences in leg length causes differences in hip and knee angels, which again cause differences in force needed to accomplish the movement. However, because people have to rise from different seat heights every day, a non-adjustable, regular sized chair was chosen.

4.3 Future Research

The current study found significant associations between gait speed, step length and lower extremity strength. It also showed gender differences in performance, in which men had higher scores in all test parameters than women, except in cadence. The results also indicated differences in the strength of the associations between different variables. The Sit-to-stand performance test was meant to be a more functional strength test than the isometric leg press test. As gait speed has been found as a global index of functioning in elderly (Studenski et al., 2003), it would have been expected that the Sit-to-stand performance test had a stronger association with gait speed, than the leg press test. Surprisingly, the results showed small differences between these associations. However, these indications were not fully explored in the current study, and further investigations are needed to fully understand the total meaning of the differences in strength of these associations.

The direction of the association between gait parameters and lower extremity strength would be of interest to investigate, as this aspect was not investigated in the current study. As mentioned earlier, Chandler et al. (1998) did a linear regression and found a strong, positive association between strength gain and gain in gait speed, but in their study other measures of lower extremity strength, and a different sample population were used. It would have been of interest to explore how much lower extremity strength will increase for each level gait speed increases. On the contrary, it would also be of interest to explore how much gait speed increases for each level lower extremity strength increases. This may be important since it can provide information about whether it is possible to maintain good function in gait by focusing on lower extremity strength training or maintaining high lower extremity strength by focusing on gait and gait speed. Maybe one direction is more beneficial than the other. This can be investigated by a prospective study containing two groups that implement different exercise programs. The first group conduct only lower extremity strength training to see if this affects their gait speed, while the other group conduct only gait training. The results of such research may be of great important regarding rehabilitation or postponement of need for care services at older ages.

5.0 CONCLUSION

In the current study the association between gait speed and lower extremity strength in elderly was investigated. The results showed that there was a significant, positive association between gait speed and lower extremity strength, with faster gait speed being associated with greater lower extremity strength. When gait speed increases, step length and cadence increases as well. Men were found to walk faster and have stronger lower extremity strength than women. Previous research seems to support the findings, but the conducting of different methods in measuring lower extremity strength must be taken into account. The result indicates differences in the strength of the associations, which along with the direction of the associations may be of interest to investigate in further research.

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