The Association between Physical Activity and Lower Extremity Strength in Older Persons

Malin Andrea Midjo

Master degree thesis

Department of Human Movement Science

Faculty of Social Science and Technology (NTNU)

Trondheim, Norway

Spring, 2013

NTNU – Trondheim
Norwegian University of
Science and Technology

Acknowledgements

The work with my master thesis has given me many insights and new knowledge about doing research and seeing a project through from start to end. For this there are many people I would like to thank.

First of all I would like to thank my excellent supervisor Beatrix Vereijken for being a great support and for giving me smart advice and sharing her knowledge about the many aspects of exercising and physical activity in the elderly. I would also like to thank my co-supervisor Per Bendik Wik for his invaluable help in performing research using a multitude of different equipment.

It has not been an easy process learning and understanding ActiGraph. It would not have been possible without the help from the superb Thorlene Egerton. I also thank Jan Erik Ingebrigtsen for our discussions and his advice about ActiGraph during this project and Espen Ihlen for his help with processing HUR data in MATLAB.

I also thank my fellow students for the many social breaks during the year, and special thanks to Ane Horten Flyen for the good teamwork in both collecting and processing the data.

Finally, thanks to my family and friends for supporting me and believing in me.

Trondheim, June 2013

Abstract

Background and aim: Age-related physiological changes are well documented, such as loss of muscle fibers and muscle strength. Although there are many studies documenting the effect of resistance training on lower extremity strength, there has been less focus on the effect of general daily-life physical activity on lower extremity strength. The main purpose of the present study is therefore to investigate whether there is an association between general physical activity and lower extremity strength. Secondary aims are to investigate whether the relationship is different for self-reported and directly measured estimates of physical activity, for different estimates of lower extremity strength, and for different levels of physical activity. Possible gender differences will also be investigated. **Methods:** 486 men and women (mean age 71.5) performed a concentric functional chair rise task, Sit-to-Stand test, and an isometric leg press task as estimates of lower extremity strength. The participants filled out a questionnaire about physical activity based on the HUNT survey. Physical activity level was also measured directly using ActiGraph GT3X accelerometers. **Results:** There was a significant moderate association between the directly measured vertical acceleration and the movement of chair rise, and the intensity of daily physical activity and movement of chair rise. There was also a strong association between the parameters derived from ActiGraph, and moderate to strong associations between some of the questionnaire parameters. Between ActiGraph and the questionnaire parameters, there is a moderate association between the total number of activity minutes per week and vertical acceleration. In addition there was a moderate association between at least 30 minutes of activity per day and acceleration in all three directions. For the lower extremity strength parameters there was a strong association both within and across the different parameters for two tasks. Both genders reported to be less active than when their daily activity was directly measured by accelerometer. The men were more physically active and stronger in the lower extremities than the women. There was also an association between physical activity and lower extremity strength for both genders, but the association is stronger with respect to the men. **Conclusion:** There is an association between physical activity and lower extremity strength. There were significant findings for all of the paratmeters, but there was only a moderate association between both directly measured and self-reported physical activity and movement of chair rise. Finally, the participants are a rather active group, but tend to underestimate their activity level. There is also an association between physical activity and lower extremity strength for both genders.

Content

Acknowledgements 2

Abstract 3

1.0 Introduction 6

1.1 Age-related changes in physical functioning 6

1.2 Physical activity 8

1.3 The present study 9

2.0 Methods 10

2.1 Participants 10

2.2 Equipment 10

2.2.1 ActiGraph accelerometer 11

2.2.2 Questionnaire 11

2.2.3 HUR leg press 12

2.2.4 Sit-to-Stand test 13

2.3 Procedure 13

2.4 Outcome measures and analyses 14

2.4.1 Physical activity 14

2.4.2 Lower extremity strength 15

2.4.3 Statistical analyses 17

2.5 Ethics 18

3.0 Results 19

3.1 Sample characteristics 19

3.2 Physical activity 19

3.3 Lower extremity strength 23

3.4 Association between lower extremity strength and physical activity 25

3.5 Lower extremity strength and accelerometer-based activity levels 27

4.0 Discussion 28

4.1 Main findings 28

4.2 Association between physical activity and lower extremity strength 28

4.3 Gender differences regarding physical activity and lower extremity strength 33

4.4 Physical activity measurements 34

4.5 Lower extremity strength measurements 38

4.6 Methodical considerations 39

5.0 Conclusion 41

References 42

1.0 Introduction

The number of elderly persons in the population is increasing and they are achieving increasingly higher age. In 2008, the amount of older people was 13 % of the population. In 2050, the number of older people over the year of 67 will have increased to 21 %, and the number of those over 80 years will have doubled (1). It is also estimated that currently, older people use about half of the healthcare services in Norway (2). The increasing need for healthcare for a growing population of elderly will affect the welfare state, and calculations indicate that the expenses of for instance fall injuries will cost 1.85 times more than a preventive program (3). In order to keep older people independent for as long as possible, meaning that they can live in their own homes and cope with everyday life activities, and limit health care costs for the society, they need to maintain their functional level and general health for as long as possible.

1.1 Age-related changes in physical functioning

Aging is a process that occurs over a relative long period of time. The process of aging can also appear at different times in different components, for example, a change in a specific organ could have an influence on the functions of other organs (4). Further, there are many changes in physical functioning that comes naturally with aging. Some of them are metabolic changes, muscle fatigue and sarcopenia, and these can cause decrease in lower extremity strength in older persons. This could further impact older peoples' everyday life through a decrease in functional ability (5). Mobility is an important component for older people being able to maintain independency in functioning. A decrease in mobility indicate a decrease in functional health, meaning not being able to performing physical tasks, such as walking the stairs and chair rising (6).

As lower extremity strength has been suggested as a determinant of physical function among functionally-limited older people (6), it is important to understand what lower extremity strength is. Muscle strength has been defined as the maximum force developing capacity of a human. It reaches its peak between the ages of 20 to 30 years and then decreases slowly until the age of about 50 years. Thereafter the decline is around 12 % to 15 % per decade, and after the age of 65 the loss is even more rapid (7). Muscle power is, among others, and estimate for muscle strength and can be defined as the product of movement and velocity (8). Further explanation about age-related changes comes next.

One of the age-related changes that can be correlated to a decrease in lower extremity strength is sarcopenia, which is defined as the loss of muscle mass, and thereby muscle strength. After the age of 60, there is a decrease in the number of motor neurons in the muscles, and this is one of the main causes of sarcopenia (9). The mass loss is basically caused by two changes, primary the loss of muscle fibers and secondly muscle fiber atrophy, especially in type 2 fibers. As the type 2 fibers contraction velocity is about 4 times higher than type 1 fibers, type 2 fibers loss is an important factor for decreased muscle mass and muscle power. If neuromuscular activity is decreased and the antagonist co-activation is increased, it can contribute to a greater reduction in muscle strength and power (9). Further, sarcopenia can cause a reduction in muscular strength of nearly 50 %, and Jespersen et al. (9) conclude in their review that the number of lost motor neurons probably cannot be reversed nor be regulated by resistance training.

Muscle fatigue is also said to be a factor for reduced muscle strength with increased age. There are many definitions of what muscle fatigue is, but can for example be explained as a transient decrease in the capacity to perform physical actions, and be measured as a reduction in muscle force (10). Muscle fatigue is not the point where the muscles are exhausted or where the task is failing. Rather, it is the reduced force or power the muscle involved can generate and occurs by degrees not long after the beginning of physical activity (10).

Another natural consequence of the aging process is reduced rate of mitochondrial protein synthesis and muscle protein synthesis (4, 11). This is vital for the continuous growth of the body and the repair and maintenance of the body's muscle groups (12). According to Volpi et al. (11), the metabolic change is linked to a reduction in, among others, ATP stores within the muscle cell and a mild reduction in overall metabolic rate. The metabolic changes in the muscle affects the physical exercise capacity of elders, and can reduce the ability to exploit oxygen during exercise, like $VO_{2max,}$ with about 30 % (11).

Several direct measures of lower extremity strength, such as isometric leg press (13), or indirect estimates as proxy for lower extremity strength are reported in the literature. For example, a test that has been used as a secondary estimate of lower extremity strength is the Sit-To-Stand test (14) as this it's a functional task that requires the use of lower extremity strength. Furthermore, muscle power has grown to be accepted as a measurement for calculating physical impairment related to age (15).

1.2 Physical activity

There are many studies investigating older people's health in order to understand what changes that occur with increasing age, how these changes may affect their lives, and what can be done in order to keep older people at good health for a longer period. Many studies also argue that physical activity is necessary for maintaining good health, regardless of gender or age (16, 17). Although there are many different types of physical activity, resistance training and endurance training are the types of activities that people most likely associate with the term physical activity. However, physical activity can also consist of taking the stairs instead of the elevator, gardening or a walk on a track or path. It can also include everyday life activities, such as cooking, cleaning, and doing laundry. What different individuals associate with the content of physical activity, can differ greatly depending on different ages, gender, and basic physical health. The latter is traditionally measured by self-reported questionnaires, which have been used in many studies (18, 19). More recently, physical activity levels are increasingly measured directly by the use of accelerometers (19, 20).

A review by Jespersen et al. (9) looked at age related changes of sarcopenia and the effects of resistance training. Their review found articles showing a 10-45% increase in lower extremity strength after resistance training over a period of 8-12 weeks (9). However, some of the increase can be explained by neural adaptions and other adaptions, and not an increased muscle mass. They conclude that if 3 months of resistance training can increase the cross-sectional area of the muscle by 10 % this would reverse a decade in muscle mass loss given a muscle mass decrease of about 1 % per year after the age of 50 years. The study also conclude that if an increase in the lower extremity strength can lead to decades of muscle mass loss being reversible, the point of time of the decreased function level can be postponed. Further, increased muscle strength seems to lead to enhanced spontaneous physical activity on a daily basis (9).

Although the focus to a great extent has been on resistance training, several studies have indicated positive effects of aerobic exercise on muscle strength as well (21). It has also been shown that aerobic exercise may positively affect muscle quality and neuromuscular adaptions of those who prior to aerobic exercise were sedentary or sarcopenic (11). The study by Sheffield-Morre et al. (21) investigated whether moderate-intensity aerobic exercise could, among others, increase the post-exercise synthesis rate of muscle proteins in both young and older men. The results pointed to an increase in muscle protein turnover as a response to the aerobic exercise in older men. Short et al. (22) have also shown that a 4 months aerobic exercises program involving mainly leg muscles, results in increased muscle protein synthesis. Another study showed that progressive aerobic training can improve muscle performance and size in healthy older women (16). The study concluded that aerobic training can be used to improve function and muscle mass in older people (16).

1.3 The present study

Maintenance or improvement of age-related changes in physical functioning, including lower extremity strength, is vital for elderly persons in order to uphold functional level in everyday life. There is far less knowledge about the association between general physical activity and lower extremity strength, than about the effects of endurance training or resistance training on lower extremity strength. There are also few studies on the importance of frequency or intensity of physical activity in order to have an effect on lower extremity strength and physical functioning.

The main aim of this study is therefore to investigate whether there is an association between physical activity and lower extremity strength in older people. Secondary aims are to investigate whether the relationship is different for self-reported estimates of physical activity versus direct measures of physical activity, and for estimations of lower leg strength based on functional task versus isometric exercises. As men on average are stronger than women potential gender differences in physical activity and the association with strength will be studied as well.

2.0 Methods

This study is a population-based cross sectional study examining whether there is an association between general physical activity and lower extremity strength in older people. It is part of a larger population-based prospective clinical project called Generation 100. This larger project is a collaboration between St. Olav's Hospital and the Norwegian University of Science and Technology (NTNU). Generation 100 investigates the relationship between physical activity and cardiovascular morbidity and mortality in older people and the effect of different intensity levels of training on cardiovascular health.

2.1 Participants

All inhabitants in the Trondheim region born between 1938 and 1942 were invited to participate in the larger Generation 100 project. Participation was voluntary and the participants received written information and a questionnaire prior to the testing day concerning the test routines and used equipment. After inclusion, they came one day to St. Olav's hospital to undergo testing (see further below). Data was collected between from August 2012 until May 2013.

The current study includes all participants tested from September 1st until mid-November. The data set used contained data from 484 participants in a Sit-to-Stand test, and data from 467 participants from an isometric leg press test. In addition, questionnaire data was available for 480 participants. When merging all the data, the total number of participants was 486, 258 women and 228 men that further analyses were based on.

2.2 Equipment

The equipment used to collect data for the present study included two different systems to estimate lower extremity strength, a functional concentric Sit-to-Stand test and an isometric HUR leg press. Physical Activity was measured with ActiGraph GT3X and through a self-reported questionnaire based on the HUNT survey. All are described in more detail below.

2.2.1 ActiGraph accelerometer

Daily activity was objectively registered with the ActiGraph™ GT3X (ActiGraph, LLC, Pensacola, Florida, USA). This is a small (5.1 × 4.1 × 1.5 cm), lightweight (0.4 kg) tri-axial accelerometer that measures vertical, anteroposterior and mediolateral acceleration at a sample rate of 30 Hz. The ActiGraph is filtered to only measure movements within a given frequency band (0.25-2.5 Hz) in order to exclude interference from other motions (23). The main ActiGraph outcome is vector magnitude (VM) that combines data from all three axes, in addition to vertical acceleration measurements (24). The outcomes are typically expressed in time intervals (epochs). The activity counts reflect the intensity of bodily movement, and the higher the number of counts, the more active a person is (23).

2.2.2 Questionnaire

The participants received the questionnaire by mail prior to the testing day. The questions about physical activity were the same ones as used in the HUNT survey (25). The questionnaire included questions about the intensity, frequency and duration of their physical activity during the last week. The frequency question was ‘How often do you exercise on average?’, with the response options *never, less than once a week, once a week, 2-3 times, a week* and *nearly every day*. Those who responded that they exercised once a week or more also answered the question about intensity, ‘If you exercise, how hard do you exercise on average?’ with the response options *no sweating or heavy breathing*, *sweating and heavy breathing*, and *nearly exhausted*. They also responded to the question about duration, ‘How long do you exercise on average?’ with the options *less than 15 minutes, 15-29 minutes, 30 minutes to an hour,* or *more than an hour* (see Figure 1, in Norwegian). In addition, all the participants answered the question ‘Do you normally have at least 30 minutes physical activity on a daily basis?’ with the response options *yes* or *no*.

Mosjon og fysisk aktivitet

Med mosjon mener vi at du for eksempel går tur, går på ski, svømmer eller driver trening/idrett. Fysisk aktivitet omfatter både fysisk aktivitet i hverdagen, planlagte aktiviteter og trening.

7. Hvor ofte driver du mosjon? (Ta et gjennomsnitt)
   - ☐ Aldri
   - ☐ Sjeldnere enn en gang i uka
   - ☐ En gang i uka
   - ☐ 2-3 ganger i uka
   - ☐ Omtrent hver dag

8. Dersom du driver slik mosjon, så ofte som en eller flere ganger i uka; hvor hardt mosjonerer du? (Ta et gjennomsnitt)
   - ☐ Tar det rolig uten å bli andpusten eller svett
   - ☐ Tar det så hardt at jeg blir andpusten og svett
   - ☐ Tar meg nesten helt ut

9. Hvor lenge holder du på hver gang? (Ta et gjennomsnitt)
   ☐ Mindre enn 15 minutter ☐ 15-29 minutter ☐ 30 minutter – 1 time ☐ Mer enn 1 time

10. Har du vanligvis minst 30 minutter fysisk aktivitet daglig? ☐ Ja ☐ Nei

Figure 1. Questions about self-reported physical activity from the HUNT survey, used in the present study as well (in Norwegian).

2.2.3 HUR leg press

Isometric muscle strength of the lower extremities was measured for each leg separately using HUR FCM 5540 Leg Press Rehab Standard (Helsinki University of Research) (Figure 2). The device has two power cells, one for each leg, and measures the exerted force at 50 Hz for 5 seconds. The device is custom made for use by older people in such a way that they can easily get in and out of the device. The software Performance Recorder (Helsinki University of Research) was used to register the results. A goniometer was used to measure the knee angle (see section 2.3).

Figure 2. The HUR leg press device custom made for older people.

2.2.4 Sit-to-Stand test

To estimate functional lower limb strength, a functional concentric Sit-to-Stand test was performed. The equipment used in the test was the software MuscleLab attached to a linear encoder. A string from the device was attached to the participants' waist with a belt during testing, and when the participants rose from the chair, the speed of the movement was measured. The chair had a height of 45 cm, was not adjustable and had no armrests.

2.3 Procedure

All testing took place at the training unit at the heart-lung center at St. Olav's Hospital. During the testing day the participants underwent different measurements, such as body mass index, blood pressure, blood samples, spirometry, grip strength, gait, leg strength, Sit-to-Stand and VO_{2max}. Only the tests used in the present study will be further described.

When testing lower extremity strength the HUR device was adjusted using a goniometer so that the participant's knee angle was at 110°. To make sure that the participants did not slide up towards the back of the leg press, they were secured with a belt over the hips. The participants' hands were placed across the chest. The testing was repeated 6 times, and the generated forces were measured three times for each leg, with a little resting break midway. The investigator counted down loud from five to zero, and gave a signal when the participant could push against the power cells. The participant was instructed to push to their maximum until the investigator gave a stop signal. Pushing time was three to five seconds, depending on whether the participant had a heart disease or not.

The Sit-to-Stand test was performed on a chair, where the starting point was sitting down on the chair. A hook from the device fastened to the participant's belt measured the speed of movement when rising. The participants were verbally instructed to stand up as fast as possible from the chair. The participant's hands were placed across the chest, and the feet should remain in contact with the ground while rising. The testing was done five times with breaks between each trial.

The ActiGraph device was pre-programmed a week prior to the testing day. By the end of the testing day, the ActiGraph was handed to the participants with instructions to wear the device around the waist with a belt continuously for at least seven days, except when showering or during water-based activities. The participants received a verbal instruction along with a written supplement.

2.4 Outcome measures and analyses

Information about physical activity was derived from the body-worn accelerometer and the self-reported questionnaire, and about lower extremity strength from the isometric and functional concentric measurement. For each of the different measurements of both physical activity and lower extremity strength several outcome measures were calculated. These will be presented next.

2.4.1 Physical activity

Information about physical activity was collected from the body-worn accelerometer ActiGraph and through questionnaires about physical activity.

The data from Actigraph GT3X was processed using the ActiLife software (ActiGraph, Pensacola, Florida, USA). The inclusion criteria for analysis were wear time for a minimum of 10 hours per day for minimum 4 days. Wear time between midnight and 6 am was excluded from the analyses. Zero counts lasting longer than 60 minutes were categorized as non-wear time and also excluded from the analysis. The variable Vector Magnitude was calculated as the square root of the sum of the squared accelerations in all 3 dimensions ($VM = \sqrt{(\text{axis1})^2 + (axis2)^2 + (axis3)^2}$). From the Vector Magnitude a new variable was created by taking the total counts of vector magnitude and dividing it by the epoch length, Vector Magnitude Average Counts per Epoch (VM). Although the variable VM was preprogrammed at 10 sec, due to different settings in some of the devices, some of the epochs were set to 60 seconds, which could not be changed in ActiLife afterwards. In order to have the same epoch time for all the participants, the data that used 10 second epochs were set to 60 second epochs by multiplying VM by 6. Counts per Minute (CPM) was calculated based on the vertical axis only.

The average time spent at different activity levels was also calculated. In the present study, the 2020 cut point was chosen for moderate intensity as the basis for the other cut points. Several other studies have used this cut point for 1 axis accelerometer data (20, 26, 27). Therefore, for the CPM parameter, the cut points were set at <1000 for Minutes in Sedentary, 1001-2020 for Minutes in Low, 2021-3000 for Minutes in Moderate and >3000 for Minutes in Vigorous activity. These parameters described the total number of minutes at each intensity level over the period of wear time. In addition Minutes in Moderate activity and Minutes in Vigorous activity were added up, creating the new variable Minutes in Moderate/Vigorous activity. Additional variables were created by dividing each intensity level by the number of days the devices were worn for each participant, resulting in the variables Average Minutes Sedentary per Day, Average Minutes Low per Day, Average Minutes Moderate per Day, Average Minutes Vigorous per Day and Average Minutes Moderate/Vigorous per Day. In sum, the following physical activity variables were derived from Actigraph: VM, CPM, and Minutes in Average Sedentary behavior, Low Physical Activity (PA), Moderate PA, Vigorous PA and Moderate/Vigorous PA.

In the questionnaire, the participants were asked about the frequency, duration and intensity of their physical activity habits during the last week. There were five response options in the frequency question (see above). Those who answered no activity or less than one time per week were classified as inactive. The participants who answered that they were physically active once per week or more were in addition asked about the average duration and intensity of their activity session (see above).

Based on an earlier study (18) that also used questions from the HUNT survey, new variables were created in the software IBM SPSS Statistics 20. The average number of hours of physical activity per week was calculated as a new variable named Physical Activity Total (PA Total) and was based on the variables *frequency* times *duration*. The response possibilities *never* and *less than 1 times per week* was counted as 0, *1 time per week* as 1, *2 to 3 times per week* as 2.5 times per week, and *nearly every day* as 5 times per week. The response possibilities *less than 15 minutes* was counted as 10 minutes, *15 to 29 minutes* as 25 minutes, *30 to 60 minutes* as 45 minutes and *more than 60 minutes* was counted as 75 minutes. In addition, the variable PA Total was divided by 7 days, creating the new variable Physical Activity per Day (PA Day). Finally, the question about at least 30 minutes physical activity per day from the questionnaire (see above), was included in the data set. In sum, the following physical activity variables were derived from the questionnaire data: PA Total, PA Intensity, PA Frequency, PA Duration, PA Day, and PA 30 min.

2.4.2 Lower extremity strength

When estimating leg strength from the Sit-to-Stand (STS) test, the outcome was the velocity in each of 5 repetitions. The variables from the Sit-To-Stand test were created by taking the mean of the last four of five trials, resulting in Average Velocity (in m/s). The first trial was counted as a test trial, and therefore excluded. A new variable, Peak velocity (in m/s), was calculated by finding the maximum peak in the last four tests.

For the HUR leg press, the outcome was force times series, which were further analyzed to identify Peak Force and Peak Rate of Force Development (RFD) for each leg in each repetition. The HUR leg press data was first processed in MATLAB R2011b (The Mathworks, Natick, MA, USA) and the resulting force profiles were manually evaluated to check whether each trial fit the inclusion criteria. Exclusion criteria were trials that started above 5 kg (indicating that the participants started pushing before the go signal) and trials that continued to rise to the end (indicating that participants were still pushing when data measurement stopped). An additional exclusion criterion was when peak of RFD appeared after peak force.

Figure 3 shows an example of a trial that met the inclusion criteria and was approved. Figure 4 shows an example of a trial that did not meet the inclusion criteria, as it started above 5 kg and force production continued to rise to the end. Figure 5 shows an example of a trial that was excluded because peak rate of force development occurred after peak force (both marked with a green ring).

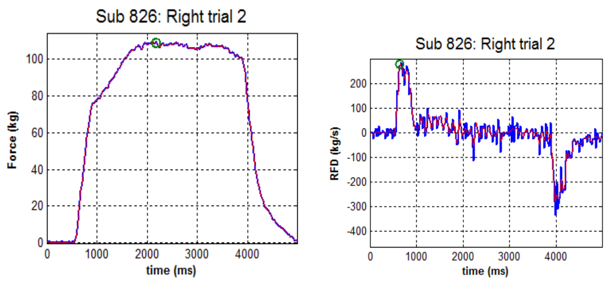

Figure 3. Example of an approved leg press trial.

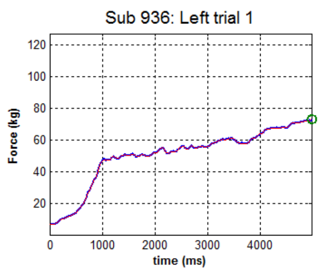

Figure 4. Example of an excluded leg press trial.

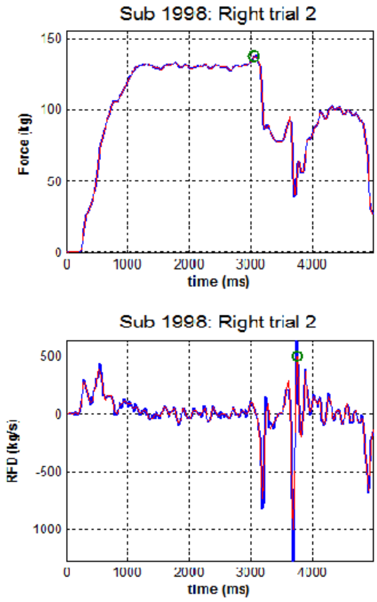

Figure 5. Example of an excluded leg press trial.

In sum, the variables from STS and HUR leg press expressing lower extremity strength are: Average Velocity, Peak Velocity, Peak Force and Peak Rate of Force Development.

2.4.3 Statistical analyses

All data was analyzed in IBM SPSS Statistics 20. Descriptive analyses were used to calculate means and standard deviations (SD) for the different variables. Pearson's correlation coefficient was used to investigate whether there was an association between leg strength and physical activity variables. Spearman's correlation coefficient was used for the non-parametric questionnaire variables. Independent samples t-test was used to test whether the mean of the variables were significantly different between the genders. In the case of the non-parametric variables, two-independent-samples Mann-Whitney test was used. As the number of participants is quite large, a Monte Carlo test was chosen. For question with only two response options, a Chi square goodness of fit test was performed. To classify the strength of the correlation between two variables the guidelines in Pallant (28) were used, where r=.10-.29 are considered weak, r=.30-.49 are considered moderate and r=.50-1.0 are considered strong.

2.5 Ethics

Participation in the Generation 100 project was voluntary and participants could at any time withdraw without any explanation. As part of Generation 100, the present study was approved by the Regional Ethical Committee in Health Region IV (REK). During testing the participants had a chair available if needed, and they were offered resting breaks whenever necessary or requested.

3.0 Results

The result section consists of 4 parts; sample characteristics, physical activity analyses, lower extremity strength analyses, and finally the association between physical activity and lower extremity strength.

3.1 Sample characteristics

The total sample consisted of 486 participants, 228 men and 258 women. Table 1 summarize the mean and SD for the participants' age, height, weight, and Body Mass Index (BMI) for all participants together and for each gender separately. In addition, results from independent-samples t-tests are presented, showing that women and men have similar age, but differ significantly with respect to height, weight and BMI, with men having higher scores than women.

Table 1. Sample characteristics of the participants and results from independent sample t-tests between women and men.

	All participants		Women		Men		Women vs Men	
	N	*Mean (SD)*	*N*	*Mean (SD)*	*N*	*Mean (SD)*	*t*	*p*
Age	467	71.5 (1.4)	246	71.6 (1.4)	221	71.4 (1.4)	.1.310	.191
Height	465	173.1 (35.5)	251	166.2 (19.8)	214	181.0 (41.5)	-4.999	**.000**
Weight	485	75.1 (12.9)	257	68.6 (10.8)	227	82.4 (11)	-13.777	**.000**
BMI	464	25.5 (3.4)	250	25.2 (3.7)	214	26.0 (3)	2.524	**.012**

Marked with bold are significantly p-values (2-tailed).

3.2 Physical activity

Information about the participants' physical activity was collected through a self-reported questionnaire and by body-worn accelerometers. The accelerometer-based variables included activity Counts Per Minute (CPM) and Vector Magnitude (VM) and the average number of minutes per day the participants spent in Sedentary behavior, Low PA, Moderate PA, Vigorous and Moderate/Vigorous PA. Questionnaire variables consisted of PA 30 minutes (yes/no), PA Intensity, PA Frequency and PA Duration, and the combined frequency x duration variable called PA Total. In addition, PA per Day (PA Total divided by 7 days) is included.

Tables 2 and 3 presents the mean and SD of the physical activity variables for all participants together, and for each gender separately. On average, participants wore the accelerometer for 7.6 days, SD 1.7. As shown in Table 2, men scored slightly higher on CPM while women scored slightly higher on VM, but these differences were not significant (both p's>0.4), independent samples t-tests).

Table 2. Mean and SD for the accelerometer-based physical activity variables for the total sample and each gender, plus results from independent samples t-tests on women versus men.

		All participants		**Women**		**Men**	**Women vs Men**	
	N	*Mean SD)*	*N*	*Mean(SD)*	*N*	*Mean (SD)*	*t*	*P*
<u>ActiGraph:</u>								
VM[a]	366	560 (171)	201	565.9 (162.1)	165	552.8 (183.4)	.725	.469
CPM[b]	366	263.7 (107)	201	255.5 (93.6)	165	273.8 (120.8)	-1.628	.474

[a]*Vector Magnitude Average Counts per Minute based on 3-axes (vertical, anteroposterior, mediolateral).*

[b] *Counts per Minute based on 1-axis (vertical).*

As shown in Table 3, women scored higher on PA Total whereas the men reported higher intensity and longer duration, but not higher frequency than the women. Results from an independent samples t-test on PA Total indicated no significant difference between the genders. For the non-parametric variables PA 30 min and PA Intensity, Frequency and Duration, Mann-Whitney tests were performed. The results showed that the genders differed significantly only on PA Intensity, where men had higher scores, $p<0.005$, and PA 30 min, where the women had higher scores, $p<0.005$. When asked whether they were physically active for at least 30 min per day, 200 out of 244 women answered yes, against 152 out of 215 men. These results were analyzed using a chi square goodness of fit test. The results showed that the Pearson Chi-Square value was 8.119, with $p<0.004$, indicating that women answered significantly more often that they were physically active for at least 30 minutes per day than men.

Table 3. Mean and SD for physical activity questionnaire variables for the total sample and each gender, plus results from independent samples t-tests and Two Independent Sample T-test, Mann-Whitney,

		All participants		***Women***		***Men***	***Women vs Men***	
	N	*Mean (SD)*	*N*	*Mean (SD)*	*N*	*Mean (SD)*	*t*	*p*
Questionnaire:								
PA Intensity[c]	456	1.6 (.5)	247	1.51 (.51)	209	1.7 (.5)	-	**.000**
PA Frequency[d]	480	3.9 (.9)	257	3.9 (.9)	223	3.8 (.9)	-	.079
PA Duration[e]	452	3.1 (.7)	244	3.2 (.6)	208	3.2 (.6)	-	.215
PA Total[f]	473	141.3 (97)	251	146.8 (100)	222	135.2 (93.2)	1.300	.194

[c-e]Physical activity questions derived from self-reported questionnaire. [f]Total amount of Physical Activity in a week (Frequency multiplied by Duration).[c-e]Two Independent Samples T-test, Mann-Whitney. [f] Independent Samples T-Test.

The number of minutes in sedentary behavior per day was very high for both women and men, namely 864 minutes or 14.24 hours (SD: W=63.6, M=66.0). Presented in Figure 6 are the scores on the other categories of physical activity level for each gender, and the amount of daily physical activity as estimated from the questionnaire data (PA Day).

On average, women spent more time in Low PA (SD: W=17.7, M=16) and Moderate PA (SD: W=9.6, M=8.1). Results from Independent Sample T-Test are also presented. Number of minutes in sedentary behavior per day were high and the same for women and men, namely 864 minutes, or 14.24 hours (SD, W=63.6, M=66). Women spent more time in Low PA (W=SD, 17.7, M=16) and Moderate PA (W=SD, 9.6, M= 8.1) than the men, who spent more time in Vigorous PA (SD: W=16.1, M=19.3) and Moderate/Vigorous PA (SD: W=20.8, M=22.2). The results on PA per Day derived from questionnaire data show that the women reported to be more active per day than the men, but both women and men reported less activity in minutes per day than measured by the accelerometer. However, men and women differed significantly only on Minutes in Vigorous PA, $p<0.05$, with men scoring higher.

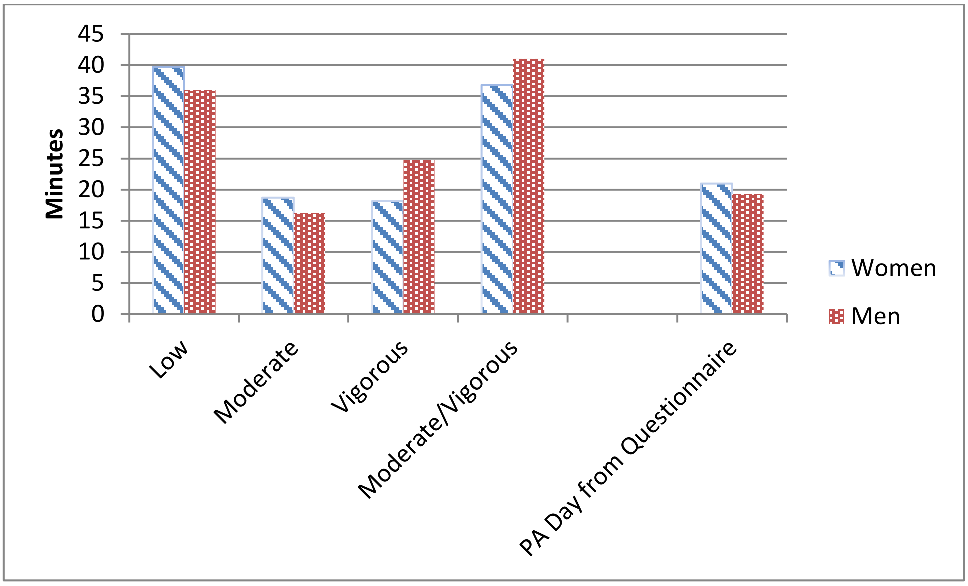

Figure 6. Average minutes per day in each of the PA categories Low, Moderate, Vigorous, Moderate/Vigorous, and Physical Activity per Day for each gender based on the questionnaire data.

Subsequently, the association between the different measures of physical activity was tested. Table 4 presents the variables derived from the body-worn accelerometer (Vector Magnitude and Counts Per Minute) and from the self-reported questionnaire (PA Intensity, PA Frequency, PA Duration and PA Total). Spearman correlation coefficients were calculated to investigate the association between the different variables.

As can be seen in Table 4, the two variables derived from the accelerometer-based data, VM and CPM, have a strong correlation, r=.897. The variables from the questionnaire show moderate to strong association between PA Total, PA Frequency, PA Duration and PA 30 min., with correlations ranging from r=.342 to r=.893. PA Intensity did not have a significant correlation with PA Frequency or PA 30 min., with correlations ranging from r=.034 to r=.085. All correlations between the variables derived from the accelerometer and those derived from the questionnaire were positive and significant, but only PA Total and CPM, and PA 30 min. and VM had a moderate strength. Otherwise the correlations between accelerometer and questionnaire data were weak, ranging r=.116 to r=.296 (see Table 4).

Table 4. Significant Spearman's correlation coefficients between the different physical activity variables.

	VM	CPM	PA Intensity	PA Frequency	PA Duration	PA Total	PA 30 min
VM[a]		**.897** *N=366*	.116* *N=345*	.202* *N=362*	.166* *N=344*	**.241** ***N=358***	**.302** *N=347*
CPM[b]			**.186** ***N=345***	**.278** ***N=362***	**.176** ***N=344***	**.307** *N=358*	**.296** ***N=347***
PA Intensity[c]				-	**.213** ***N=451***	.147 ***N=473***	-
PA Frequency[d]					.115* *N=451*	**.893** *N=473*	**.343** *N=458*
PA Duration[e]						**.533** *N=451*	.115* *N=439*
PA Total[f]							**.351** *N=453*
PA 30 min.[g]							

*Marked in bold are significant results at p<0.01 (2-tailed) * Correlation is significant at p <0.05 (2-tailed). Not significant correlations are indicated by* **-.** *[a, b] Derived from ActiGraph. [c-g] Derived from self-reported questionnaire.*

3.3 Lower extremity strength

Lower extremity strength information was measured through isometric leg press and estimated from a functional strength task. The isometric leg press variables included peak Force and peak RFD. Functional task variables were average Velocity and peak Velocity. Table 5 presents the mean and SD of lower extremity strength variables for each gender. In addition the results from independent samples t-tests are presented.

Men had higher values than the women on all variables. The results from the independent samples t-tests confirmed that men and women differed significantly in Average Velocity, Peak Velocity, Peak Force and Peak RFD, with men having higher scores, all p's <0.005 (Table 5).

Table 5. Mean and SD for the lower extremity strength variables for each gender, plus results from Independent Sample T-tests.

		All Subjects		**Women**		**Men**	**Women vs Men**	
	N	*Mean (SD)*	*N*	*Mean (SD)*	*N*	*Mean (SD)*	*t-value*	*p-value*
Average Velocity[a]	485	.5780 (.17)	257	.4866 (.13)	227	.6814 (.15)	-14.707	**.000**
Peak Velocity[a]	485	1.1776 (.26)	257	1.0297 (.2)	227	1.3447 (.21)	-16.429	**.000**
Peak Force[b]	467	91.90 (37)	246	69.38 (22)	221	116.97 (33.9)	-17.977	**.000**
Peak RFD[b]	467	294 (174)	246	197.55 (102.7)	221	401.36 (177.3)	-15.572	**.000**

Marked in bold are significant results at p <0.01(2-tailed). [a] Derived from Sit-To-Stand test. [b] Derived from HUR leg press.

Subsequently, the association between the different parameters of lower extremity strength was tested using Pearson's correlation coefficients. Table 6 presents the results from the functional STS task (Average Velocity and Peak Velocity), and from the isometric leg press (Peak Force and Peak RFD).

The two variables derived from the STS test have a strong association, r=.873. The same goes for the variables from the HUR leg press, r=.741. The association between the variables from the two different tests are also strong, varying between r=.501 to r=.591 (Table 6).

Table 6. Pearson's correlation coefficient between the lower extremity strength variables.

	Average Velocity	**Peak Velocity**	**Peak Force**	**Peak RFD**
Average Velocity[a]		**.873** *N=485*	**.560** *N=465*	**.501** *N=465*
Peak Velocity[a]			**.587** *N=465*	**.559** *N=465*
Peak Force[b]				**.741** *N=467*
Peak Rate of Force Development[b]				

Marked in bold are significan results at p <0.01(2-tailed). [a] Derived from Sit-To-Stand test. [b] Derived from HUR leg press.

3.4 Association between lower extremity strength and physical activity

Presented in Table 7 are the variables for lower extremity strength and physical activity. Table 8 presents the results for each gender separately. Lower extremity strength variables stem from isometric leg press and the functional STS task. Physical activity variables stem from the body-worn accelerometer and the self-reported questionnaire. Both Spearman and Pearson's correlations were calculated.

As shown in Table 7, the results indicate that there were many significant correlations, $p < 0.05$, but only CPM and Peak Velocity have a strong association, r=.307, together with PA Intensity and Average and Peak Velocity, r=.327 and r=.312, respectively. Otherwise, all significant associations are weak. PA Total did not have significant correlations with either Peak Force or Peak RFD, while PA Frequency and PA 30 min. did not correlate significantly with any of the strength parameters, with correlations ranging from r=-0.005 to r=0.088.

Table 7. Significant Spearman and Pearson's correlation coefficients for lower extremity strength variables and physical activity variables.

	VM[a]	**CPM[b]**	**PA Intensity[c]**	**PA Frequency[d]**	**PA Duration[e]**	**PA Total[f]**	**PA 30 min[g]**
Average[h] Velocity	**.207** *N=365*	.238 *N=365*	**.327** *N=454*	-	**.145** *N=450*	.103* *N=471*	-
Peak Velocity[i]	**.250** *N=365*	.307 *N=365*	**.312** *N=454*	-	**.128** *N=450*	.112* *N=471*	-
Peak Force[j]	-	.133* *N=352*	**.297** *N=439*	-	**.124** *N=435*	-	-
Peak RFD[k]	**.115** *N=352*	**.168** *N=352*	**.287** *N=439*	-	**.105** *N=435*	-	-

*Marked in bold are significant results <0.01 (2-tailed). *Correlation is significant at <0.05 (2-tailed). Not significant are marked with* **-**. *[a ,b, ,f] and [h-k] Pearson's Correlation coefficient analyses. [c, d, ,e, g] and [h-k] Spearman's Correlation coefficient analyses. [a ,b] Derived from ActiGraph. [c-g] Derived from self-reported questionnaire. [h, i] Derived from the STS test. [j, k] Derived from HUR leg press.*

As men were significantly stronger than women on all 4 strength parameters, associations between strength and activity were also calculated for each gender separately. As shown in Table 8, the women had a moderate association between Peak Velocity and VM, otherwise the associations were weak, ranging from r=.130 to r=.282. Furthermore, women had no significant associations with Peak Force or Peak RFD except for CPM, with r=.150. For the men, there were moderate associations between Peak Velocity and VM and CPM. Further, men had no significant associations between Peak Force and PA Frequency, Duration, PA Total, PA 30 min., and between Peak Rate of Force Development and PA Frequency, Duration and PA 30 min., ranging from r=.066 to r=.298.

Table 8. Significant Spearman and Pearson's correlation coefficients for lower extremity strength variables and physical activity variables for each gender.

		VM[c]	**CPM[c]**	**PA Intensity[d2]**	**PA Frequency[d2]**	**PA Duration[d2]**	**PA Total[d1]**	**PA 30 min.[d2]**
Women	**Average Velocity[a]**	**.282** *N=200*	**.233** *N=200*	**.242** *N=246*	.149* *N=256*	.130* *N=243*	**.163** *N=250*	**.198** *N=243*
	Peak Velocity[a]	**.343** *N=200*	**.236** *N=200*	**.223** *N=246*	.157* *N=256*	**.213** *N=243*	**.208** *N=250*	.160* *N=243*
	Peak Force[b]	-	.150* *N=191*	-	-	-	-	-
	Peak RFD[b]	-	-	-	-	-	-	-
Men	**Average Velocity[a]**	**.246** *N=165*	**.217** *N=165*	**.207** *N=208*	**.190** *N=222*	-	.170* *N=221*	.162* *N=214*
	Peak Velocity[a]	**.376** *N=165*	**.344** *N=165*	**.187** *N=208*	**.219** *N=222*	-	**.198** *N=221*	**.235** *N=214*
	Peak Force[b]	.161* *N=161*	-	**.280** *N=203*	-	.149* *N=202*	-	-
	Peak RFD[b]	**.229** *N=161*	.179* *N=161*	**.298**	-	-	.141* *N=215*	-

*Marked in bold are significant results at p <0.01 (2-tailed). *Correlation is significant at p <0.05 (2-tailed). Not significant are indicated by* **-.** *[a] Derived from STS test. [b] Derived from HUR leg press. [c] Derived from ActiGraph. [d] Derived from questionnaire. [d2] and [a,b] Spearman correlation coefficient. [c, d1] and [a,b] Pearson's correlation coefficient.*

3.5 Lower extremity strength and accelerometer-based activity levels

The accelerometer data was also used to estimate minutes spent daily at different levels of physical activity. The associations between lower extremity strength variables (both leg press and Sit-To-Stand) and these activity levels is presented in Table 9, based on Pearson's correlation coefficients.

Interestingly, none of the strength variables have a significant correlation with minutes per day spent sedentary or in Low or Moderate PA. In contrast, all correlations between minutes in Vigorous or Moderate/Vigorous PA and the strength variables are significant, ranging from r=.121 to r=.322. When stratifying for gender, these correlations were still significant, p<0.05, and weak correlations for both genders, varying from r=.191 to r=.241 for women and from r=.212 to r=.291 for the men.

Table 9. Significant Pearson's correlation coefficient across all participants between minutes spent at each activity level and lower extremity strength variables.

	N	Average Velocity[f]	Peak Velocity[f]	Peak Force[g]	Peak RFD[g]
Average Minutes Sedentary[a]	366	-	-	-	-
Average Minutes Low[b]	366	-	-	-	-
Average Minutes Moderate[c]	366	-	-	-	-
Average Minutes Vigorous[d]	366	.249*	**.322**	.148*	**.202**
Average Minutes Moderate/Vigorous[e]	366	**.206**	**.260**	.121*	**.188**

*Marked in bold are significant results at p <0.01 (2-tailed).*Correlation is significant at p <0.05 (2-tailed). Not significant are indicated by* **-.** *[a-e] Average Minutes participants spent in each PA category, derived from ActiGraph, 1-axis. [f] Derived from STS test. [g] Derived from HUR leg press.*

4.0 Discussion

The main aim of the present study was to investigate whether there is an association between physical activity and lower extremity strength in older people. Secondary aims were to investigate whether the relationship is different for self-reported estimates of physical activity versus directly measured physical activity, and for estimates of lower extremity strength, derived from a functional task versus measures in an isometric task. As men on average are stronger than women, the present study also investigated gender differences in physical activity, lower extremity strength, and the association between strength and activity. Physical activity was measured directly from a body-worn accelerometer and from self-reported questionnaires. Lower extremity strength was measured in an isometric leg press and estimated from a functional concentric strength task.

4.1 Main findings

There is an association between physical activity and lower extremity strength in older people. The association is, however, only moderate between the vertical acceleration of movement and movement velocity when rising from a chair. There is also an association between the intensity of the physical activity and the chair rise velocity. The different levels of physical activity were all significant, but there was only moderate correlation between the number of minutes spent in vigorous activity and the velocity of movement. Further, looking at the different parameters derived from the different measurements, there were moderate to strong associations both between the parameters derived from the same measurements and across the different measurements. Finally, the men were stronger in the lower extremities and more physical active than the women. Interestingly, the women reported to be more active than the men in several parameters from the questionnaires.

4.2 Association between physical activity and lower extremity strength

The present study found an association between physical activity and lower extremity strength. There was also a significant association between all of the different physical activity levels and lower extremity strength parameters, but the correlation was weak for all parameters, except between minutes spent at vigorous activity and velocity of movement, where the correlation was moderate. These results are consistent with several earlier studies. For example, Tarpenning et al. (29) investigated the influence of chronic endurance training and age on leg strength in adult men. They found that the age at which there was a significant decrease in strength could be delayed by chronic endurance training (29). Another study by Scott et al. (30) investigated the association between ambulatory activity and leg strength parameters in community-dwelling older women. They found that ambulatory activity for at least seven days was needed to maintain leg strength and muscle quality (30). Buchman et al. (31) assessed the association of physical activity and leg strength with change in mobility in older persons. They found that the higher the levels of physical activity and leg strength, the slower mobility declines (31). Common for these studies is that they do not explain the associations with an increase in strength per se, but with maintenance, deceleration, or delay of different age-related changes, such as mobility decline (29-31). Interestingly, the results in the different studies point in the same direction, despite having used vastly different measurements, equipment, and parameters for estimating physical activity and lower extremity strength. This indicates that irrespective of how one measures or estimates lower extremity strength, the association with physical activity becomes apparent in the results.

In the present study, there is no information about when the participants started being physically active, i.e. whether they started at a young age, pension age or at other ages, but it is reasonable to expect large individual differences. Nevertheless, there is an association between physical activity and lower extremity strength. There are few studies that might shed a light on how people's past may affect this association. A study by Chang et al. (32) investigated whether physical activity in midlife maintains the function in the lower extremities when getting older. Their results showed that there is a long term association between physical activity and lower extremity function, and that those who were physically active at midlife had better function in their lower extremities than those who were inactive at midlife (32). The next question to ask may be whether this maintenance will keep up if older people continue late-life exercises. A review by Keysor and Jette (33) investigated whether increased exercise can improve function and whether exercise can prevent or decrease disability in older people. Their study showed that over half of the studies reviewed indicated positive effects of late-life exercise with respect to, among others, strength, aerobic capacity, walking and standing balance. Late-life exercise has, therefore, important benefits on physiological parameters and physical function. However, the review points out that there is not enough evidence about whether resistance training and aerobic conditioning alone have an effect on those who already have a disability (33). This is supported by Chandler et al. (13), who found no association between lower extremity strength, endurance and disability.

However, their study also indicated that lower extremity strength gain is associated with an increase in confidence related to mobility. Another review by Ozaki et al. (34) found that it is possible that walking, jogging or sporadic running over a period of six months can increase leg muscle size, but that the increase in muscle size and strength may depend on intensity, duration, and environment of the performed activity (34).

Almost all of the findings in the abovementioned studies' (29-34) support the findings of an association between physical activity and lower extremity strength in the present study, but the associations in these studies are, as previously mentioned explained in a variety of different ways. However, the current study cannot determine potential causality. It is possible that older persons who are physically active experience increase or maintenance in lower extremity strength, or that those with stronger lower extremities can be more physically active. The relationship may also be circular, with increased physical activity leading to stronger lower extremities, which in turn enables increased physical activity. This circular causality would create a positive circle between physical activity and becoming more functional. Which of these alternatives is the better explanation is not possible to determine in the present study, but further research should focus on estimating whether such an association stems from a maintenance or improvement, or to what extent the association is influenced by the participants' earlier activity behavior or environmental influences.

In the present study, the results indicated that there is no association between at least 30 minutes of physical activity per day and lower extremity strength. There is, however, an association between number of minutes spent in vigorous activity and lower extremity strength, despite the former being under 30 minutes. The study by Brach et al. (35) found that older people who exercised for 20 to 30 minutes almost every day tend to experience better physical functioning than those who were active throughout the day or inactive. These results correspond with the findings from the accelerometer-based activity levels in the present study. However, they do not coincide with the results from the self-reported question about at least 30 minutes of physical activity per day in the present study, which did not have an association with lower extremity strength. It is also interesting that there is no association between the number of minutes spent in moderate/vigorous activity and lower extremity strength, even though this is more than 30 minutes on average per day.

When evaluating all of the abovementioned studies results, it is important to keep in mind that the results stem from different parameters calculated from different measurements, such as body-worn accelerometer, questionnaires, and different lower extremity task. Despite these differences, the different types of measurement of lower extremity strength in previous studies, the robust association with physical activity points to the importance of having enough strength so that older people can keep up with everyday activities. Chandler et al. (36) state that in order to perform a specific activity ‘normally’, a certain amount of strength is necessary. Below such a threshold of strength, it might become critical to perform an activity, such as rising from a chair or walking stairs. Furthermore, one might assume that it may not be as important what kind of physical activity older people do, as long as they are active and are able to do everyday life activities. As Brach et al. (35) concluded in their study, it is better for older people to do any kind of physical activity than to be inactive, in order to prevent or delay possible age-related limitations. It is important that physical function and general health are maintained or improved in order to enable older people to live at home and be independent for as long as possible.

As previously mentioned, there is an association between vigorous activity and lower extremity strength. In addition, the results from the vertical accelerometer show that men on an average had 273.8 counts, while women had 255.5 counts per minute per day (Table 2). When looking at the number of minutes they spent in moderate to vigorous activity, the men had 41 minutes while the women had 37 minutes per day (Figure 6). These results indicate that the participants in the present study are relatively active people. Although there were no VO_{2max} measurements in the present study, looking into other studies using the same or nearly the same body-worn accelerometer and adjustments to the device as the present study can give additional information. There are no previous studies that have used the same accelerometer-based activity levels as the one used in the present study, so direct comparisons with earlier results is not possible. There is, however, a study (27) from Reykjavik, Iceland, that investigated the daily physical activity patterns and sedentary behavior in older people using data from the vertical accelerometer on the same device as the one used in the present study. The results from the age group 73-74.9 showed that their activity counts per minute were about less than a third of the counts in the present study for both men and women (27). Does this really mean that the participants in the present study are more than three times as active as older people in the Icelandic study? The Icelandic study concluded that older people in Iceland have a habit of swimming in the warm headwaters, and that environmental factor, such as short summers, might have affected the results, in addition to the fact that the testing was done in April 2009 to June 2010 (27). As the accelerometer is not measuring while swimming, this could make the activity counts far less than they should have been. However, such an environmental factor could also affect the results in the present study, as the measuring was done in September to November. Autumn in Trondheim is known for its ‘four seasons in a day’ weather, and could have affected the motivation to be physical active outdoors in poor weather. However, the results in the Icelandic study are similar to the results in the study by Troiano et al. (26). They also used the vertical measurement from a body-worn accelerometer (ActiGraph 7164) when investigating the physical activity level for children, adults, and older people in the US.A. Their results indicated that older people over the age of 70 were about less than a third of the activity counts for men and women than the results from the present study. The differences in this study and the present study could stem from the use of two different devices for the vertical acceleration. However, the USA results are still far less than the activity counts in the present study. If these results can be trusted and compared, they would indicate that the participants in the present study are a very active group of people compared to people from Iceland and USA.

Keeping the above differences and resulting limitations for a direct comparison in mind, a comparison is made for the results of activity counts above 2020 per day across the different studies. The Icelandic study (27) showed that the men had approximately one fourth of the activity counts in present study, while the women had approximately one sixth of the activity counts in the present study. In the American study (26), the men had about one fifth of the counts from the present study, while the women had less than one sixth of the activity counts. Both of the above mentioned studies’ counts are far less than the results from the present study where the men had, as previously mentioned, 41 and women 37 minutes per day. Even though the differences in the results are large and could indicate something about the physical activity level for older persons in Norway versus other countries, it is not that straightforward to compare the results in the three studies. The present study uses the same criteria as the Icelandic study (27) in the processing of the accelerometer data, but differed with respect to inclusion of activity counts from between midnight to 6 pm. The American study (26) might have differences in the processing of the data, in addition to using a different type of accelerometer device. Finally, it is also important to keep in mind that Norway, Iceland and USA have different cultures, health care systems and habits of everyday life, which could affect the results differently and indeed lead to differences in activity levels.

Irrespective of possible differences in equipment, measurements and analyses, the participants in the present study are a relatively physically active group, as they adhered to the recommendation from the Health department of Norway (36) of at least 30 minutes of physical activity per day. Simultaneously, the frailest older people might be missing in the sample. Those who have an interest in their own general physical health and are aware of their age-related changes would likely be the ones to respond positively to being a part of a training study such as Generation 100. This could cause a selection bias. The participants' awareness of their physical activity level being measured while wearing the accelerometer could also cause them to give an extra effort activity-wise, giving them higher results than they otherwise might have gotten. This could at least in part explain why there was only an association between vigorous activity and lower extremity strength. As Chandler et al. (13) pointed out, theoretically, when the strength is below the threshold necessary for a specific activity, the relationship between strength change and change in performance might well be stronger than for the people whose strength is above this threshold. If the frailer part of the population had been a part of the current sample as well, it would have been interesting to see whether their presence would have affected the association between levels of activity and lower extremity strength. One of the important aspects to look at would be whether there are certain levels of lower extremity strength and physical activity that are required in order to function in everyday life. Finally, the present study indicates that there is an association between daily life physical activity and lower extremity strength and functioning. Further analyses on the data from the Generation 100 study could shed light on whether this association is different for groups of older people having different levels of activity in their life.

4.3 Gender differences regarding physical activity and lower extremity strength

The results indicated that the men in the sample, according to the direct physical activity measurements, were more physically active than the women, with the men having higher scores both in vertical acceleration only and acceleration in all three directions. The men also had higher scores in vigorous and moderate to vigorous activity levels. However, the women reported to be more active than the men in the questionnaire. Furthermore, the men were stronger in their lower extremities than the women.

As physical activity level decreases with aging, an increase in sedentary behavior is associated with a loss of muscle strength (37). Furthermore, a study Lührmann et al. (38) found a gender difference in physical activity, with men spending more time in sport activities, while women were more active doing household work. The Icelandic study (27) also found that men were more active than the women, but only with respect to more vigorous levels of physical activity. This could mean that as the women are more active in the lower levels of activity, these levels might represent activities such as household chores. If so, this would be consistent with the findings in the study by Lührmann (38) and probably the present study as well with respect to the difference in the activity levels.

The gender differences in muscle strength to the advantage of men are well documented and supported by several studies (39-41). It has also been found that there is a gender difference in the characteristics of sarcopenia, also to the advantage of men. However, sarcopenia seems to be related to increasing age, where it for men appears at a later stage than the women (40). This could coincide with the results in the present study, where the women have lower scores than men in lower extremity strength as well as lower r-values for the association with physical activity than men. This could indicate that at similar age, sarcopenia is at less advanced stage for men than women. Furthermore, a decrease in mobility is experienced with increasing age where the women have more problems with maintenance of mobility than the men (42). These findings coincide with the present study's results, where men have a stronger association between functional task and physical activity.

Why the men are more active than the women could be related to physiological differences, with men having greater muscle mass than women (40). This could give an advantage to the men, in allowing them to be more physically active. As previously mentioned above, this could lead to better function in the lower extremities, creating a positive circle between physical activity and strength. However, this is not possible to establish this in the present study. The gender differences in the scores in the lower extremities tests are also discussed in chapter 4.5.

4.4 Physical activity measurements

The results in the present study indicated that there are differences between directly measured physical activity and self-reported physical activity through a questionnaire. Both women and men are more active than they report to be through the questionnaire. Furthermore, vertical acceleration alone had a stronger association with lower extremity strength than accelerations in all three directions combined. Which of the different measurements is more reliable? And to what extent can one trust the associations found in the current study if they depend on the specific measurements?

To measure physical activity either directly or through self-reported questionnaire can cause challenges. Studies that investigated the reliability and validation of both the HUNT survey 1 and 2 questionnaire, showed that questions about time spent in moderate and vigorous physical activity are acceptable to utilize in research about physical activity, but reliability for low or light physical activity still needs to be established (43, 44). Another validation study has shown that compared with an accelerometer, the validity of questionnaires is weaker (45). For the results in the present study, this may indicate that the participants indeed are more physically active, and spent more time in moderate to vigorous physical activity, than they estimated themselves through the self-reported questionnaire. These findings do not, however, correspond with the study by Sallis and Saelens (46), who indicated that the physical activity levels estimated by both young and older people tend to be higher than the objectively measured physical activity level. Why might the present study have found different result than other studies? One hypothesis can be that older persons underestimate their own health, and may therefore assume that their physical activity levels are lower than they actually are. Although, this is difficult to support without further investigation, it would be interesting to investigate another question in the questionnaire about how they comprehend their own health. It is important to keep in mind that the interpretation of moderate to vigorous activity in the activity levels derived from accelerometer versus self-reported frequency and duration of the activity might be different, making it difficult to directly compare the parameters. In addition, the minutes at different activity levels from ActiGraph is summed up from activity throughout the day, while the questions about physical activity from the questionnaire indicate a consecutive period of activity. Furthermore, the questionnaire and accelerometer device in the study by Sallis and Saelens (46) were not the same as the ones used in the present study, and one should therefore be careful making a direct comparison between these studies as well.

Another challenge with estimating physical activity in older people lies in the 1-axis versus all three axes from the body-worn accelerometer. Other studies using the same device intended the use for children, adults or for children, adults and older people combined. Most of the activity levels derived from accelerometers in other studies on older people were based on the vertical accelerometer only, such as 7164 or GT1M (26, 27, 47). There are few studies that have used the three accelerometer device in older people. Therefore, setting the activity levels in the processing of the data was a long and difficult process, without information from previous studies on which cut-off values to use. An earlier validation study on ActiGraph

GT3X set the activity level for moderate activity to count between 2690-6166 (48). However, the study pointed out that the activity levels in the study might not be generalizable to other groups, such as older people (48). Therefore, there seems to be no earlier studies where activity levels based on all three directions were validated for older people. In the present study the activity level cut offs were set using the vertical acceleration only and not all three accelerations, and was based on other studies using only the vertical acceleration activity level of 2020 for moderate activity (26, 27, 47).

As mentioned above, the results in the present study indicated that the vertical acceleration had higher associations with lower extremity strength than acceleration in all three directions. This could at first sight indicate that a measurement in vertical acceleration might be preferred when measuring older people. Yet, one would assume that an accelerometer measuring in vertical, anteroposterior and mediolateral direction would be a more accurate measurement. The latter is probably the case, as the validation study by Sasaki et al. (49) found that acceleration in all three directions provided a more excellent activity monitor to measure physical activity than the vertical acceleration only. The difference in the results between vertical acceleration only and acceleration in all three directions could therefore be caused by the ‘inverted-U phenomenon’ that have been detected in both GT1M (vertical acceleration) and the vertical acceleration of the GT3X device. As explained by Sasaki et al. (48), the phenomenon is when increased running speed passes the threshold of the band-pass filter of the monitor, and cause a leveling of the activity counts. To the extent this only happens when running at high speed, it is unlikely that this can cause the discrepancy in the current results. The study also points out that so far no studies have compared the differences between using vector magnitude in all three directions and vector magnitude in vertical acceleration only when measuring physical activity (48). Therefore, it would be interesting to look further into the distribution between vertical, anteroposterior and mediolateral accelerations derived from the ActiGraph device to investigate the importance of vertical acceleration compared to the other two accelerations. In addition to also find out what kind of activity that would cause most movement in the three different accelerations. A study by Kavanagh et al. (49) investigated the upper body acceleration of young and older people to see whether there are any differences while walking. They found that the correlation between head and trunk acceleration was stronger for vertical acceleration, followed by anteroposterior and mediolateral acceleration (49). This coincides with the results in the present study, where the vertical direction has a stronger association than the acceleration in all three directions. It also supports the observations made while testing and talking with the participants, where many of the older people listed outdoor walking as a preferred activity However, in order to establish the differences between vertical acceleration and acceleration in all three directions, it would be useful to measure the pulse synchronous with the accelerometer device.

There might also be other reasons for the vertical acceleration to be associated better with lower extremity strength than acceleration in all three directions. A study by Dean et al. (50) found that older people have a larger energetic cost in habitual gait than younger people, and that a part of this could be through lateral foot placement or other motions to actively control balance. When the step width was smaller, the energetic cost was also increased, explained with increased difficulty with active balance control and the need to move the swing foot around the posture foot (50). This could indicate that the nature of older people's gait is 'heavier' than younger people, which further can affect the counts in the accelerometer and lead to more activity counts per minute.

There is an important limitation about body-worn accelerometer worth mentioning. Namely, it is not possible to get information on what kind of physical activity the participants are doing through only the activity counts from the accelerometer. If two participants have the exact same counts, it does not necessarily mean that they are equally physically active. One of the participants might have a spread activity level throughout the day, while the other one might be moderately active for half an hour and be sedentary for the rest of the day. Both people do not need to be in the same shape. However, the distribution of activity counts during the period of measurement was not available for the present study, and could therefore not be investigated.

Finally one should be careful concluding about the association with strength from self-reported parameters alone, but consider them in combination with other parameters that inform about physical activity. In sum, the accelerometer device, perhaps especially in vertical acceleration, might well be the preferred measurement of physical activity for older people, both in relation to the simplicity of the measuring and the nature of their physical activity habits, meaning that they might prefer walking as an activity. Assessing the differences in the directly measured and self-reported minutes in activity levels and the hypothesis of the participants underestimating their own health, it could indicate possibilities of recall bias. Yet, even though there are several challenges associated with self-reported questionnaires, the benefit of reporting on physical activity conditions is highly valuable in population studies (51).

4.5 Lower extremity strength measurements

When looking at the association between the lower extremity strength parameters, the results in the present study indicate that there is a strong correlation between the parameters from the HUR leg press, the Sit-To-Stand tests, and between these two measurements.

As previously mentioned, the STS test is often used as an indicator of lower extremity strength. According to Schurr et al. (52), the test has excellent reliability, but when used in a busy rehabilitation environment the test have a moderate responsiveness. There are, however, a few limitations in the testing protocol. First and foremost, the chair was not adjustable, so that those who were either fairly short or fairly high had and additional challenge with the test compared to those who had an average height that fitted the height of the chair. This limitation was also highlighted in the study by Schurr et al. (52).

The HUR leg press had several limitations as well. First of all, it has not previously been used in a population study like the Generation 100 project nor has it been validated for an older population. However, the analyses in the current study indicated strong correlations between the different parameters both within and across two tests. However, these strong associations indicate that both the HUR leg press device and the Sit-To-Stand test are measuring the same underlying lower extremity strength function. In addition, there are some practical challenges with both the device design and the software. During testing, several participants criticized the back of the device, saying it had too steep ascent. However, the back on the device could not be adjusted. Furthermore, although the distance of the seat could be adjusted, the participants who were rather short or fairly high had problems getting a knee angle at 110°, which could make it more difficult to produce max isometric strength. In addition, the software for the device measured only one leg at a time. This means that in between testing each leg, a cable needed to be swapped.

The STS test and HUR leg press provided different parameters, and it might be interesting to look further into each of the parameters. The results in the current study indicated that the women had no significant association between physical activity and HUR leg press parameters, except from the vertical acceleration. These results reflect the observations made during the testing, where some of the women seemed to not understand the task fully, or not being able to produce max isometric strength. Some of the women also got a ‘trampoline effect’, pushing alternating with each leg, leading to poor trials that had to be excluded. This could also be the case for some of the men who had never been into a gym or tried a leg press before. Both men and women seemed to understand the functional concentric task better, as the results are more even between the gender and the association to physical activity is stronger between the STS test parameters than the HUR leg press parameters. This could indicate that it is easier for both men and women to do functional tasks, such as STS test, which further could make the participants get a result that reflects their strength ability.

Other factors can also have affected the performance in the testing.

A study by Pojednic et al. (51) indicated that movement velocity is a determinant of the capability of power production that becomes increasingly influential with aging and with decreased lower mobility functioning. However, another study (52) stated that force is the more important contribution to age-related reduction in muscle power compared to velocity. Furthermore, Pojednic et al. (51) stated that because isometric assessments allow more time for motor units to be recruited, the assessment might be less sensitive in the measuring. On the contrary, during a dynamic task, the mechanisms underlying force production might not have enough time to get engaged during testing, which could lead to poorer results. The latter result is not consistent with the findings from the present study, where the association is weaker with the Force and RFD parameters than the movement of velocity parameters. However, the above results are investigating respectively the association between movement velocity and lower mobility function, and force and muscle power, and not physical activity as the present study is investigating. Nevertheless, these results are interesting to keep in mind considering which parameter to use when investigating lower extremity strength or function in future studies. Finally, both the STS test and the HUR leg press seem to be good measurements to indicate lower extremity strength, but velocity of movement might be preferred as an indicator for lower extremity strength for older people. In addition, some upgrading and adjustment of the HUR leg press software could make the device more compatible to use in a larger project, such as Generation 100.

4.6 Methodical considerations

There are a few strengths and weaknesses in the present study that should be mentioned. The total number of participants was 486, giving a relative large sample number. For the measurements of both physical activity and lower extremity strength there were several different parameters, giving various options for comparison. Although, the included participants seemed to be fairly active, which is positive, this could also indicate that the frailest older persons were not included in the study. There may be several reasons for this, related to poor health, low interest to participate in research and/or a training study, or insufficient information what the study was about. Several of the participants mentioned that they originally declined to participate in the larger Generation 100 project, but changed their mind when hearing from others who had participated how well they enjoyed taking part in the project. This could affect the generalizing of the results to other older people. In addition, by using a questionnaire, recall bias can occur, even though it was only a week back in time. Finally, during in the processing of the raw ActiGraph data, an error was discovered in the calculations of the vector magnitude 3-axes. Although the software was later updated by the ActiGraph Company and the data analyzed again, there might be additional, unknown errors in the software.

5.0 Conclusion

The present study investigated the association between general, daily physical activity and lower extremity strength in older people. The results indicated that there is indeed an association, particularly between directly measured physical activity and movement velocity. These findings are consistent with previous studies focusing in resistance training, endurance training and aerobic exercise. Whether the association is caused by an increase of strength, maintenance of physical functioning, or both, cannot be settled in the present study. There were significant findings for both physical activity and lower extremity strength parameters, but there was only a moderate association between both directly measured and self-reported physical activity and movement of velocity from chair rise. Finally, the participants in the present study seem to be a rather active group of older people, who tend to underestimate their daily self-reported physical activity level when compared to their directly measured physical activity level. The men are also more physical active in vigorous activity and are stronger in the lower extremities than the women, but there is an association between physical activity and lower extremity strength for both genders.

References

1. Statistisk Sentralbyrå, *Dette er Norge, Hva tallene forteller, Revidert utgave 2009.* http://www.ssb.no. 2009: p. 4.

2. Sosial- og helsedirektoratet. *Fysisk aktivitet og helse, anbefalinger*. http://www.helsedirektoratet.no. 2002: p. 12.

3. Hektoen, L.F., Aas, E., and Lurås, H., *Cost-effectiveness in fall prevention for older women*. Scand J Public Health, 2009. 37: p. 584–589

4. Nair, K.S., *Aging Muscle 1-5*. Am J Clin Nutr, 2005. 81: p. 953– 963.

5. Helbostad, J.L., Sturnieks, D.L., Menant, J., Delbaere, K., Lord, S.R., and Pijnappels, M., *Consequences of lower extremity and trunk muscle fatigue on balance and functional task in older people: A systematic literature review*. BMC Geriatrics. 2010. 10:56.

6. Reid, K.F., Naumova, E.N., Carabello, R.J., Phillips, E.M., and Fielding, R.A., *Lower Extremity Muscle Mass Predicts Functional Performance in Mobility-Limited Elders*. J Nutr Health Aging, 2008. 12(7): p. 493–498.

7. Macaluso, A., and Vito, G.D., *Muscle strength, power and adaptions to resistance training in older people.* Eur J Appl Physiol, 2004. 91: p. 450–472

8. Foldvari, M., Clark, M., Laviolette, L.C., Bernstein, M.A., Kaliton, D., Castaneda, C., et al., *Association of muscle power with functional status in community-dwelling elderly women*. Journal of Gerontology: MEDICAL SCIENCES, 2000. 55(4): p.192-199.

9. Jespersen, J., Pedersen, T.G., and Beyer, N., *Sarkopeni og Styrketræning*. Ugeskriv Læger, 2003. 165(35): p. 3307-3311.

10. Enoka, R.M., and Duchateau, J., *Muscle fatigue: what, why and how it influences muscle function*. J Physiol, 2008. 586 (1): p. 11-23.

11. Volpi, E., Nazemi, R., and Fujita, S., *Muscle tissue changes with aging*. Curr Opin Clin Nutr Metab Care, 2004. 7(4): p.405-410.

12. World of Sport Science, *Muscle protein synthesis*. http://www.faqs.org/sports-science. 2013

13. Chandler, J.M., Duncan, P.W., Kochersberger, G., and Studenski, S., *Is Lower Extremity Strength Gain Associated With Improvement in Physical Performance and Disability in Frail, Community-Dwelling Elders?* Arch Phys Med Rehabil, 1998. 79: p.24-30

14. McCarthy, E.K., Horvat, M.A., Holtsberg, P.A., and Wisenbaker, J.M., *Repeated chair stands as a measure of lower limb strength in sexagenarian women.* Journal of Gerontology: MEDICAL SCIENCES, 2004. 59A(11): p.1207-1212.

15. Bean, J.F., Kiely, D.K., LaRose, S., Goldstein, R., Frontera, W.R., and Leveille, S.G., *Are changes in leg power responsible for clinically meaningful improvements in mobility in older adults?* J Am Geriatr Soc, 2010. 58(12): p.2363-2368.

16. Harber, M.P., Konopka, A.R., Douglass, M.D., Minchev, K., Kaminsky, L.A., Trappe, T.A., et al. *Aerobic exercise training improves whole muscle and single myofiber size and function in older women*. Am J Physiol Regul Integr Comp Physiol, 2009. 297(5): p.1452-1459.

17. Leveille, S.G., Guralnik, J.M., Ferrucci, L., and Langlois, J.A., *Aging successfully until death in old age: opportunities for increasing active life expectancy.* Am J Epidemiol, 1999. 149(7): p.654-664.

18. Nilsen, T.I.L., Holtermann, A., and Mork, P.J., *Physical Exercise, Body Mass Index, and Risk of Chronic Pain in the Low Back and Neck/Shoulders: Longitudinal Data From the Nord-Trøndelag Health Study.* Am J Epidemiol, 2011. 174(3): p. 267–273.

19. Davis, M.G., and Fox, K.R., *Physical activity patterns assessed by accelerometry in older people*. Eur J Appl Physiol, 2007. 100(5): p.581-589.

20. Matthews, C.E., Chen, K.Y., Freedson, P.S., Buchowski, M.S., Beech, B.M., Pate, R.R., et al., *Amount of time spent in sedentary behaviors in the United States, 2003-2004*. Am J Epidemiol, 2008. 167(7): p.875-881.

21. Sheffield-Moore, M., Yeckel, C.W., Volpi, E., Wolf, S.E., Morio, B., Chinkes, D.L., et al., *Postexercise protein metabolism in older and younger men following moderate-intensity aerobic exercise*. Am J Physiol Endocrinol Metab, 2004. 287(3): p.513-522.

22. Short, K.R., Vittone, J.L., Bigelow, M.L., Proctor, D.N., and Nair, K.S., *Age and aerobic exercise training effects on whole body and muscle protein metabolism*. Am J Physiol Endocrinol Metab, 2004. 286(1): p.92-101.

23. Hall, K.S., Howe, C.A., Rana, S.R., Martin, C.L., Morey, M.C., *METs and accelerometry of walking in older adults: standard versus measured energy cost. Medicine and science in sports and exercise*. Med Sci Sports Exerc, 2013. 45(3): p.574-582.

24. John, D., and Freedson, P., *ActiGraph and Actical physical activity monitors: a peek under the hood. Medicine and science in sports and exercise*. Med Sci Sports Exerc, 2012. 44(1): p. 86–89.

25. NTNU, *Questionnaires from the HUNT studies.* http://www.ntnu.edu/hunt/data/que. 2013.

26. Troiano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., and McDowell, M., *Physical activity in the United States measured by accelerometer.* Med Sci Sports Exerc, 2008. 40(1): p.181-8.

27. Arnardottir, N.Y., Koster, A., Domelen, D.R.V., Brychta, R.J., Caserotti, P., Eiriksdottir, G., et al., *Objective measurements of daily physical activity patterns and sedentary behaviour in older adults: Age, Gene/Environment Susceptibility-Reykjavik Study*. Age and Aging, 2013. 42: p.222–229.

28. Pallant, J., *SPSS Survival Manual*. Australia, Allen & Unwin Book Publishers, 2010.

29. Tarpenning, K.M., Hamilton-Wessler, M., Wiswell, R.A., and Hawkins, S.A., *Endurance training delays age of decline in leg strength and muscle morphology*. Med Sci Sports Exerc, 2004. 36(1): p.74-78.

30. Scott, D., Blizzard, L., Fell, J., Jones, G., *Ambulatory activity, body composition, and lower-limb muscle strength in older adults*. Med Sci Sports Exerc, 2009. 41(2): p.383-389.

31. Buchman, A.S., Wilson, R.S., Boyle, P.A., Tang, Y., Fleischman, D.A., Bennett, D.A., *Physical activity and leg strength predict decline in mobility performance in older persons*. J Am Geriatr Soc, 2007. 55(10): p.1618-1623.

32. Chang, M., Saczynski, J.S., Snaedal, J., Bjornsson, S., Einarsson, B., Garcia, M., et al., *Midlife physical activity preserves lower extremity function in older adults: age gene/environment susceptibility-Reykjavik study*. J Am Geriatr Soc, 2013. 61(2): p.237-242.

33. Keysor, J.J., and Jette, A.M., *Have we oversold the benefit of late-life exercise?* Journal of Gerontology: MEDICAL SCIENCES, 2001. 56(7): p.412-423.

34. Ozaki, H., Loenneke, J.P., Thiebaud, R.S., Stager, J.M., Abe, T., *Possibility of leg muscle hypertrophy by ambulation in older adults: a brief review.* Clinical interventions in aging, 2013. 8: p.369-75.

35. Brach, J.S., Simonsick, E.M., Kritchevsky, S., Yaffe, K., and Newman, A.B., *The association between physical function and lifestyle activity and exercise in the health, aging and body composition study*. J Am Geriatr Soc, 2004 52(4): p.502-509.

36. Helsedirektoratet, *Anbefalinger*. http://www.helsedirektoratet.no, 2011.

37. Milanovic, Z., Pantelic, S., Trajkovic, N., Sporis, G., Kostic, R., and James, N., *Age-related decrease in physical activity and functional fitness among elderly men and women*. Clinical interventions in aging, 2013. 8: p.549-56.

38. Lührmann P.M., Bender, R., Edelmann-Schäfer, B., and Neuhäuser-Berthold, M., *Longitudinal changes in energy expenditure in an elderly German population: a 12-year follow-up*. Eur J Clin Nutr, 2009. 63: p.986–992.

39. Frontera, W.R., Hughes, V.A., Lutz, K.J., and Evans, W.J., *A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women*. J Appl Physiol, 1991. 71(2): p.644-50.

40. Fragala, M.S., Clark, M.H., Walsh, S.J., Kleppinger, A., Judge, J.O., Kuchel, G.A., et al., *Gender differences in anthropometric predictors of physical performance in older adults*. Gender Medicine, 2012. 9(6): p.445-56.

41. Silva, A.M., Shen, W., Heo, M., Gallagher, D., Wang, Z., Sardinha, L.B., et al., *Ethnicity-related skeletal muscle differences across the lifespan.* Am J Hum Biol, 2010. 22(1): p.76-82.

42. Tseng, L.A., Delmonico, M.J., Visser, M., Boudreau, R.M., Goodpaster, B.H., Schwartz, A.V., et al., *Body Composition Explains Sex Differential in Physical Performance Among Older Adults.* J Gerontol A Biol Sci Med Sci, 2013.

43. Kurtze, N., Rangul, V., Hustvedt, B.E., and Flanders, W.D., *Reliability and validity of self-reported physical activity in the Nord-Trondelag Health Study: HUNT 1*. Scand J Public Health, 2008. 36(1): p.52-61.

44. Kurtze, N., Rangul, V., Hustvedt, B.E., and Flanders, W.D., *Reliability and validity of self-reported physical activity in the Nord-Trondelag Health Study (HUNT 2).* Eur J Epidemiol, 2007. 22(6): p.379-387.

45. Chinapaw, M.J., Slootmaker, S.M., Schuit, A.J., van Zuidam, M., and van Mechelen, W., *Reliability and validity of the Activity Questionnaire for Adults and Adolescents (AQuAA)*. BMC medical research methodology, 2009. 9:58.

46. Sallis, J.F., and Saelens, B.E., *Assessment of physical activity by self-report: status, limitations, and future directions*. Res Q Exerc Sport, 2000. 71(2): p.1-14.

47. Pruitt, L.A., Glynn, N.W., King, A.C., Guralnik, J.M., Aiken, E.K., Miller, G., et al., *Use of accelerometry to measure physical activity in older adults at risk for mobility disability*. Journal of aging and physical activity, 2008. 16(4): p.416-34.

48. Sasaki, J.E., John, D., and Freedson, P.S., *Validation and comparison of ActiGraph activity monitors.* Journal of science and medicine in sport / Sports Medicine Australia, 2011. 14(5): p.411-416.

49. Kavanagh, J.J., Barrett, R.S., and Morrison, S., *Upper body accelerations during walking in healthy young and elderly men.* Gait & posture, 2004. 20(3): p.291-298.

50. Dean, J.C., Alexander, N.B., and Kuo, A.D., *The effect of lateral stabilization on walking in young and old adults*. IEEE transactions on bio-medical engineering, 2007. 54(11): p.1919-1926.

51. Shephard, R.J., *Limits to the measurement of habitual physical activity by questionnaires*. British journal of sports medicine, 2003. 37(3): p.197-206.

52. Schurr, K., Sherrington, C., Wallbank, G., Pamphlett, P., and Olivetti, L., *The minimum sit-to-stand height test: reliability, responsiveness and relationship to leg muscle strength*. Clinical rehabilitation, 2012. 26(7): p.656-663.

53. Pojednic, R.M., Clark, D.J., Patten, C., Reid, K., Phillips, E.M., and Fielding, R.A., *The specific contributions of force and velocity to muscle power in older adults.* Experimental gerontology, 2012. 47(8): p.608-613.

54. Yamauchi, J., Mishima, C., Nakayama, S., and Ishii, N., *Force-velocity, force-power relationships of bilateral and unilateral leg multi-joint movements in young and elderly women*. Journal of biomechanics, 2009. 42(13): p.2151-2157.