ABSTRACT

Background and Purpose: It is not known whether short functional performance tests used in aging research are appropriate for use in healthy older adults. The purpose of this study was to investigate age-group differences (6^{th} decade *vs.* 7^{th} decade) in selected functional performance tests and the association between lower extremity strength and functional performance.

Methods: One hundred and fifty nine (18.2% (n=29) male) healthy older (mean (standard deviation) age: 60.4 (5.3) years) adults were recruited from the University of Limerick Campus Community. Knee extensor (KE) peak torque (PT) was assessed from a maximal voluntary isometric contraction (MVC). Subsequently, participants completed 10m maximal and habitual gait speed tests, 5 repetition and 30-second chair rise tests and a 900m gait speed test.

Results and Discussion: There was no difference in 10m gait speed between those in the 6^{th} and 7^{th} decade ($P>0.05$). Compared to the 6^{th} decade, those in the 7^{th} decade required an extra 39 seconds to complete 900m, an extra 0.6 seconds to complete 5 chair rises and performed 2 less chair rises in a 30-second time period ($P<0.05$). All tests had a weak association with KE strength (r=0.226 - 0.360; $P<0.05$), except for 900m gait speed which had a moderate association (r=-0.537; $P<0.001$). Our findings suggest that gait speed tests ≤10m cannot detect age-related difference in functional capacity when used in healthy older adults.

Conclusion: Extended physical performance tests should be used in aging research on healthy older adults.

Key words: ADL, knee extensor, strength, ageing

INTRODUCTION

The assessment of functional limitation is the third diagnostic criteria for sarcopenia after the assessment of muscle mass and strength. Functional limitations refer to an individual's physical or mental capability without reference to the social context.[1] A gait speed of 0.8 – 1.0m/s has been suggested as a criterion for identifying those at risk of sarcopenia.[2,3] Gait speed (8 foot), the ability to rise from a chair (5 times) and balance tests (semi-tandem and tandem stands) have been included in the short physical performance battery (SPPB), which has been validated in older adults and found to predict nursing home admission.[4] Furthermore, older adult performance on the SPPB or tests of similar difficulty have been associated with laboratory measures of muscle mass and function. Low relative skeletal mass has been shown to be associated with performance on the SPPB.[5] Increasing knee extensor (KE) strength has been associated with improved walking speed and the ability to rise from a chair[6,7] and increasing KE power has been linked to improved self-reported[8] and objectively measured (SPPB; stair climbing) physical performance.[9]

Functional performance measures such as those within the SPPB or similar tests such as gait speed tests less than or equal to 10m and chair rise tests of less than or equal to 5 repetitions have primarily been used to assess functional limitation in frail older adults over the age of 65 years[10-12] up to and including 95 years.[8] However, changes in muscle quality, which precede functional limitation, become noticeably different to a young adult at the beginning of the 6th decade.[13-18] Comparatively, there is little data on the functional capability of healthy older adults and consequently, little is known about the time course and transition to a reduction in functional capability in those prior to 65 years. Reductions in aerobic capacity and muscle function are inevitable even in masters athletes[19,20] but tracking age-related difference in functional capability amongst healthy older adults provides a challenge due to the heterogeneity of their functional capabilities. Ideally functional performance measures would be related to the performance of activities of daily living (ADL) but also able to distinguish meaningful gradations of functional capability and change over a wide range of abilities.

Test batteries such as the SPPB may suffer from a ceiling effect when used in healthy cohorts.[21] A healthy older adult may perform short gait speed or chair rise tests in a similar manner to a young adult meaning the tests cannot detect change where expected. One option to combat this effect is to use extended tests of chair rise ability or gait speed. This may allow participants to perform to a greater physiological maximum and therefore distinguish more subtle gradations of capacity in healthy adults. Some authors[22,23] have proposed extended tests such as the 30-second chair stand test and the 6-minute walk test[23,24] as a method to combat the floor effect, that is where an older adult may not be able to complete a fixed distance or number of chair rises. Tests of this nature may also have the potential to derive meaningful performance data for healthy older adults.

Although test-retest reliability for gait speed and chair rise tests has previously been described in those greater than or equal to 60 years[23-27] it has not been described in healthy adults greater than or equal to 50 years. Furthermore, a learning effect has been reported during the measurement of voluntary strength in healthy adults naïve to a laboratory environment.[28] Investigations into whether a learning effect exists in the measurement of functional performance are required to ensure criterion validity of the data reported. Assuming reliable measures of functional performance can be determined, it remains to be observed whether gait speed tests less than or equal to 10m and chair rise tests less than or equal to 5 repetitions can detect age-related difference in the functional capability of healthy older adults. Furthermore, it remains to be observed whether extended tests of functional performance offer greater sensitivity in detecting age-related change in functional capacity.

Finally, given the association between strength and functional performance in older adults[29-32] and the fact that strength at a single time point is predictive of future mobility limitation[33] it is important to determine whether there is an association between short or extended functional performance tests and laboratory measures of lower extremity muscle strength in healthy adults between 50 and 70 years of age. The purpose of this study was to a) determine test-retest reliability of functional performance using short (10m gait velocity, 5 chair stands) and extended (900m gait velocity and the number of chair stands in 30-seconds) tests, b) to determine the efficacy of short and extended tests of functional performance in detecting age-related difference between the 6th and 7th decade in healthy older adults and c) to examine the association between maximal voluntary isometric torque of the knee extensors and performance in short or extended tests of functional capability in the same sample.

METHODS

A convenience sample (n=204) of healthy older (50 – 70y) adults was recruited via email and word of mouth from the University of Limerick campus community and surrounding area to take part in the University of Limerick Healthy Aging Study.[28,34,35] For the present investigation, 159 older adults mean age (standard deviation) of 60.4 (5.3) years from the sample volunteered to participate; 18.2% (n=29) were male. There were 11 (15.5%) and 18 (11.3 %) males in the 50 – 59y and 60 -70y age brackets respectively. Participants received a full medical screening and physical examination prior to the assessment of a maximal voluntary contraction (MVC) and functional performance. Those defined as healthy, i.e. disease free based on Greig et al.[36] and living independently were invited to participate. Disease free included the absence of clinical, cardiovascular or musculoskeletal abnormality as determined by a medical doctor. Participants were required to be healthy but not masters athletes. After receiving a complete explanation of the procedures, benefits and risks of the study, all participants gave their written informed consent. Testing was carried out between

January 2011 and May 2013. This study was approved by the Research Ethics Committee of the University of Limerick (EHSREC 10-RA03).

Participants presented to the laboratory in a tracksuit or comfortable clothing suitable for exercise. Participants were tested during 2 identical sessions held 7 days apart, at the same time of day in order to reduce the potential for a learning effect previously identified in the measurement of strength in this population.[28] All measurements were carried out by the same exercise scientist, who was blind to age, to exclude issues with inter-tester reliability and reduce risk of bias. Warm up consisted of 5 minutes on a bicycle ergometer (Monark Ergomedic; 828E) at an intensity of 40 watts. The entire sample (n=159) completed a MVC, a 5 repetition chair rise test and an extended 900m gait speed test. A smaller proportion of the sample (n=65/159) completed 10m gait speed tests due to preliminary analysis which suggested the tests could not detect age-related difference in gait speed where expected. The 30-second chair rise test was added to the University of Limerick Healthy Aging Study at the midway point and therefore also has a smaller sample size (n=91/159).

Maximal Voluntary Knee Extensor Strength Measurements

Maximal voluntary isometric contractions of the knee extensors of the dominant limb (limb used to kick a ball) were measured using a Con-Trex MJ Dynamometer (Con-Trex MJ; CMV AG, Dubendorf, Switzerland). Peak isometric torque was measured in Newton-Meters. Participants were seated with a hip flexion angle of 110°. The back of the knee joint was on the edge of the seat with a knee angle of -60° from anatomical zero (180°). The distal shin pad of the dynamometer was attached 4-5cm proximal to the medial malleolus using a velcro strap. The dynamometer rotational axis was aligned with the lateral femoral condyle (knee joint axis of rotation). Participants were instructed to perform 2 submaximal voluntary isometric contractions (50 and 75% of perceived maximum) prior to each test series as in

Maffiuletti et al.,[37] with a 1 minute rest period in between. The participant then performed 3 MVC's of the knee extensors separated by 2 minutes of rest. An MVC produced a measure of isometric peak torque in a single effort which required greater than 200ms and was sustained for at least 250ms. Disqualification of an MVC from further analysis was based on the following criteria: (a) an attempt not sustained for MVC; identified by an impact spike prior to 300ms, (b) an attempt containing an initial countermovement; identified by a visible drop/rise in the torque signal greater than 5 N·m or (c) an attempt with a non-linear time-torque trace; identified by a double movement. Repeated peak torque values within a coefficient of variance (CV) of 5% which satisfied the criteria for MVC were accepted for analysis. A detailed breakdown of the strength assessment procedures including within and between day reliability are available in our recently published manuscript.[28]

10m Gait Speed Tests

Gait speed was assessed using timing gates (Micro-Gate, Polifemo, Bolzano, Italy) separated by 1.5m positioned at 0 and 10m of a measured walkway. Participants stood at the beginning of a track marked by a white line and from a static start were instructed to walk at their 'normal' pace to assess habitual gait speed. Participants were instructed to walk as fast as they could without running in the case of maximal gait speed. Participants had an open walkway for deceleration. Each trial condition was repeated twice.

Chair Rise Tests

The ability to rise from a chair was assessed using a chair, 44cm from the floor, which was placed against a wall for support. Participants were instructed to sit upright away from the back rest of the chair with their arms crossed against their chest. Participants were asked to perform one full chair stand prior to completing the test in order for them to establish a preferred foot position. Participants began the test from a seated position and were asked to complete 5 chair rises as fast as possible. Participants were informed that only chair rises in which they reached full extension from the seated position would be counted. The exercise scientist held the watch and only communicated verbally with the instructions "Go" and "Stop" at the beginning and end of the test. Subsequently, with no defined rest period, using the same positioning and technique participants were instructed to perform as many chair rises as possible in a 30-second time period. The 5 repetition chair rise test always preceded the 30-second chair rise test. Each test was performed once on each of the two test days.

Extended Gait Speed Test

Extended gait speed was assessed using a timed 900m test. Participants were brought to an indoor track which measured 225m per lap. Participants were instructed to complete four laps of the track as fast as they possibly could. The majority of participants used one or a combination of running, jogging or walking to complete the test. No instruction was provided as to correct pacing but tests were performed twice separated by 7 days to ensure adequate habituation to the test had taken place. The purpose of this test was to allow participants to perform to a greater physiological maximum than allowed by the 10m tests.

Statistical Analysis

The data were analysed using SPSS 22.0 for Windows (SPSS, Inc., Chicago, IL, USA). A 2-way mixed model intraclass correlation coefficient (ICC) was used to assess absolute agreement as it indicates the error in measurements as a proportion of total variance in measures. Cross-tabulation was used to determine the proportion of males and females in the respective age-categories. Pearson's Chi-Square test was used to determine whether differences in the proportions of males between groups were statistical different. The difference in functional performance between test days was reported using a paired sample t-test. To report descriptive statistics for PT and functional performance, a Kolmogorov-

Smirnov or Shapiro-Wilk test was conducted to determine normality. Mean and standard deviation (SD), median and interquartile range (IQR), and 95% or boostrap 95% confidence intervals (CI) are reported. Cross-sectional age or gender-related difference in peak torque (PT) and functional performance were analysed using an independent samples t-test or a Wilcoxon signed rank test for normal and non-normal data respectively. Pearson's r was used to report the association between PT and functional performance. Simple linear regression analysis was used to assess the variance in functional performance accounted for by knee extensor (KE) PT (Figure 1). Removal of outliers visible on the scatter plot did not alter the statistical significance or category of association and therefore they were not removed. Stepwise linear regression was used to assess whether sex or BMI affected associations between PT and functional performance for the sample as a whole and separated by age categories. Functional capability (gait speed or chair rise) was entered as the dependent variable and PT, sex (1=female, 2=male) and BMI were entered as independent variables.

RESULTS

Table 1 displays physical characteristics for the 159 healthy adults between 50 and 70 years of age who participated in this study. Physical characteristics are presented separately for those in the 6th (n=71) and 7th (n=88) decade of life. The proportion of men and women in the 6th (15.5% and 84.5% respectively) and 7th decade (20.5% and 79.5% respectively) was not statistically different (P=0.421). KE torque and 900m gait speed were the only measures where performance between men and women differed (P<0.05).

Reliability of Estimate

Our functional performance measures included habitual and maximal 10m gait speed, 5 repetition and 30-second chair stand performance and 900m gait speed. Test-retest reliability, for the assessment of all functional performance measures tested on two separate occasions separated by 7 days, is displayed in Table 2. Reliability was affected by a learning effect between test days which led to a statistically significant increase in performance (P<0.05) on day 2. The 900m test was the only measure of functional performance not previously used in the literature but demonstrated the highest ICC (0.880; 95% CI 0.811 - 0.925). Age-related difference in measures of functional performance and associations with KE-PT are reported from the highest values recorded from both days.

Age-related Difference in Functional Performance

Table 3 displays age-related difference in functional performance. 10m habitual (P=0.095) and maximal (P=0.856) gait speed were not different between those in the 6^{th} and 7^{th} decade. Both 5 repetition (8.2 (2.6) seconds *vs.* 8.8 (2.5) seconds; P=0.006) and 30-second (16.5 (5) *vs.* 14.0 (5); P=0.028) chair rise tests were lower for those in the 7^{th} decade. Those in the 7^{th} decade had an 11.3% (0.29m/s; 95% CI 0.12 - 0.46; P=0.001) lower gait speed when completing 900m compared to those in the 6^{th} decade.

The Association between Lower Extremity Strength and Functional Performance

PT normalised for body mass was 14.2% (0.2N·m/kg; CI 0.08 - 0.33; P=0.001) lower for older adults in the 7^{th} decade of life compared to their young counterparts in the 6^{th} decade. Other than 900m performance, all measures of functional performance had a weak (r=0.226 – 0.360; P<0.05) association with KE-PT (Table 4). Performance in the 900m gait speed test had a moderate association (r=0.537; P<0.001) with KE-PT. Sex and BMI did not have a statistically significant effect on associations between KE-PT and functional performance (P>0.05).

DISCUSSION

Repeated measurement of functional performance separated by 7 days revealed a statistically significant learning effect in the form of a performance improvement on day 2 (P<0.05).

These findings highlight the importance of the need to reduce the learning effect observed with performance tests in healthy older adults. Neither habitual nor maximal 10m gait speed could determine age-related difference in functional capacity, in essence confirming our hypothesis that shorter gait speed tests may suffer from a ceiling effect in the assessment of healthy older adults. The 900m extended gait speed test highlighted an 11.3% difference in performance between those in the 6^{th} and 7^{th} decade of life. Both short and extended chair rise tests were capable of detecting age-related difference in muscular power and endurance respectively. The chair rise and extended gait speed test confirm that tests centered on lower extremity power and/or tests which allow performance to a greater maximum can effectively combat the ceiling effect evident with use of short gait speed tests in healthy older adults. All measures of functional performance had a weak to moderate association (r=0.226 - 0.534; $P<0.05$) with knee extensor strength.

Gait Speed

Diagnostic criterion for sarcopenia is considered to be a gait speed of less than 0.8 – 1.0 m/s.[2,3] The mean habitual gait speed in the present investigation was 1.5m/s which demonstrates the relative health of our sample in comparison to a cohort with sarcopenia. It is therefore somewhat unsurprising that neither 10m habitual nor maximal gait speed test were capable of detecting age-related difference between the 6^{th} and 7^{th} decade. Glenn et al.[21] provide support for these findings, in a sample of similar age (61.5 years), size (n=102) and habitual gait speed (1.44 m/s). The authors report no difference in habitual gait speed between older adults who are sedentary, recreationally active or masters athletes and no difference in maximal gait speed between those who are sedentary or recreationally active. However, our results must be interpreted in light of the small number of participants who completed 10 m gait speed tests in the 50 – 59 year (n=37) and 60 -70 year (n=28) age brackets respectively. In the present study, the extended gait speed test revealed differences in functional capacity where expected between the 6th (n=71) and 7th decade (n=88). In addition to its construct validity, this test demonstrated high reliability and has been reported to be sensitive to change during a short term (12 weeks) resistance training intervention.[35] We report an 11.3% difference in gait speed between the 6th and 7th decade (2.56 m/s *vs.* 2.27 m/s; *P*=0.001) which is similar to the 11.3% (1.53 m/s *vs.* 1.35 m/s) difference reported by Rikli and Jones[38] between the 7th and 8th decade. Although this appears to suggest a similar per decade decline between the 6th and 7th decade, it must be acknowledged there are differences in test administration such as our test was of fixed distance and participants were allowed to run compared to the 6-minute walk test which is not of fixed distance and requires participants to remain walking. There is potential in our test, that the mean gait speed could be inflated or underestimated by the number of participants choosing to run or walk. Despite these differences both tests allow participants to perform to the maximum of their ability for an extended distance (400 – 900m) or duration (6 to 6.5 minutes) and therefore relative differences in performance can be compared with caution.

Chair Rise Tests

Participants in the 7th decade of the present study performed approximately 2 less chair rises than those in the 6th decade (14 (5) *vs.* 16.4 (3.5); *P*=0.028) in a 30-second time period. The 14 chair rises performed by those in the 7th decade is comparable to the 14.3 chair rises for those in the 7th decade reported by Rikli and Jones[38] and represents a 13.3% – 14.5% difference between the 6th and 7th decade. Our results therefore help to extend the work of Rikli and Jones[32] in the 7th, 8th and 9th decade by providing values, albeit in a smaller sample, for the 6th decade of life. The finding of a detectable difference in 5 repetition chair rise performance (8.2 (2.6) seconds *vs.* 8.8 (2.5) seconds; *P*=0.008) between decades might not have been expected due to our hypothesis that shorter tests would suffer from a ceiling effect. It may be that as the 5 repetition chair rise test is a test of lower extremity power, the difference more closely represents the observed difference in KE-PT normalised for body mass (1.48 (0.45) N·m/kg *vs.* 1.27 (0.34) N·m/kg; *P*=.001). These explanations must be interpreted whilst being aware that the observed change (7.3%) in 5 repetition chair rise performance between decades is similar to the CV (7%) for repeated measures between test days.

Knee Extensor Strength and Functional Performance

Knee extensor strength was 14% lower for those in the 7th decade, a finding consistent with the 8 – 15% per decade change in strength reported in adults between 40 – 70 years.[28,39,40] Knee extensor strength explained greater than or equal to 10% of the variance in maximal 10 m gait speed, 5 repetition and 30-second chair rise tests (Figure 1) but 29% of the variance in extended gait speed. Buchner et al.[41] reported 17% of the variance in gait speed (15.2m) to be explained by lower limb strength (knee extensor and flexor, ankle plantar and dorsi flexors) in 60 – 96 year old men and women. Ostchega et al.[6] reported 20% of the variance in 6 m gait speed to be explained by KE-PT in adults greater than or equal to 50 years. However, comparisons are limited both in test duration and population sampled. To the authors knowledge, the timed 900m test is the first extended gait speed assessment in which more than 25% of the variance can be explained by lower extremity strength in healthy older adults. This is a large proportion of the variance considering that endurance performance is also dependent upon cardio-respiratory capacity and peripheral muscular adaptations such as capillary and mitochondrial density. The fact that increasing gait speed is associated with increasing muscle strength during a test with a gait speed range of 1.3m/s – 4.3m/s is encouraging. This means the relative muscular effort for those with the mean gait speed (2.27 m/s – 2.56 m/s) is considerably less when walking at a normal healthy gait speed (1.5m/s) for an extended period of time. A reduction in the relative effort required to perform ADL has important implications towards the goal of prolonging independent living and quality of life.

Limitations

Our findings are limited to a relatively small (n=159) convenience sample of healthy older adults from the University Campus Community and surrounding areas. Furthermore, when comparing the findings of short and extended performance tests, it should be noted that while all participants (n=159) had a measure of strength, 5 repetition chair rise time and 900m gait speed, less than half (n=65) had a measure of 10 m gait speed. Despite the 900m gait speed test being sensitive to age-related difference in functional performance and having the strongest association with lower extremity strength, the lack of control over the number of participants walking, jogging or running may have over or underestimated our gait speed and therefore influenced the strength of the associations reported. Our strength measures are normalized to body mass and not the relevant segment of upper leg lean tissue or skeletal mass that was measured by the dynamometer which may alter the association seen in the present study. It remains to be seen whether strength normalised for body mass or strength per unit skeletal or lean tissue (muscle quality) has a stronger association with functional performance. We did not assess participants for stage of the menopause, cognitive function or depression, nor did we control for habitual physical activity, therefore it is unknown how these cofounding variables may have affected our results. Finally, education and socioeconomic status have been reported to influence the health of a population,[42] we have not controlled for this and our sample may be subject to a greater health bias due to being recruited from a University campus community.

CONCLUSION

The majority of functional performance tests (4/5) used in this investigation demonstrated a learning effect evidenced by a performance improvement on day 2 of assessment. This investigation demonstrated 10m gait speed tests not to have the sensitivity to report age-related difference in the functional capacity of healthy older adults. The extended tests in this investigation demonstrated construct validity by being able to distinguish differences in functional performance between healthy adults in the 6th and 7^{h} decade of life. The 900m gait speed test also had a greater association with KE strength than previous gait speed associations reported in the literature. Future research should seek to determine a) whether the observed learning effect in the assessment of functional capability is attenuated after a third test day and b) what the relative contributions of muscle mass, strength and quality (strength per unit tissue) are to functional capability in healthy older adults.

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Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest aside from grant funding stated above.

Statement of human and animal rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

REFERENCES

1. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med.* 1994;38(1):1-14.

2. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European working group on sarcopenia in older people. *Age Ageing*. 2010;39(4):412-423.

3. Fielding RA, Vellas B, Evans WJ, et al. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *J Am Med Dir Assoc.* 2011;12(4):249-256.

4. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol.* 1994;49(2):M85-94.

5. Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. *J Am Geriatr Soc.* 2002;50(5):889-896.

6. Ostchega Y, Dillon CF, Lindle R, Carroll M, Hurley BF. Isokinetic leg muscle strength in older americans and its relationship to a standardized walk test: data from the national health and nutrition examination survey 1999-2000. *J Am Geriatr Soc*. 2004;52(6):977-982.

7. Hairi NN, Cumming RG, Naganathan V, et al. Loss of muscle strength, mass (sarcopenia), and quality (specific force) and its relationship with functional limitation and physical disability: the Concord Health and Ageing in Men Project. *J Am Geriatr Soc.* 2010; 58(11):2055-2062.

8. Foldvari M, Clark M, Laviolette LC, et al. Association of muscle power with functional status in community-dwelling elderly women. *J Gerontol A Biol Sci Med Sci.* 2000;55(4):M192-199.

9. Bean JF, Kiely DK, Herman S, et al. The relationship between leg power and physical performance in mobility-limited older people. *J Am Geriatr Soc.* 2002;50(3):461-467.

10. Pahor M, Blair SN, Espeland M, et al. Effects of a physical activity intervention on measures of physical performance: Results of the lifestyle interventions and independence for Elders Pilot (LIFE-P) study. *J Gerontol A Biol Sci Med Sci.* 2006;61(11):1157-1165.

11. Vasunilashorn S, Coppin AK, Patel KV, et al. Use of the Short Physical Performance Battery Score to predict loss of ability to walk 400 meters: analysis from the InCHIANTI study. *J Gerontol A Biol Sci Med Sci.* 2009;64(2):223-229.

12. Volpato S, Cavalieri M, Sioulis F, et al. Predictive value of the Short Physical Performance Battery following hospitalization in older patients. *J Gerontol A Biol Sci Med Sci.* 2011;66(1):89-96.

13. Janssen I, Heymsfield SB, Wang ZM, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. *J Appl Physiol.* (1985). 2000;89(1):81-88.

14. D'Antona G, Pellegrino MA, Adami R, et al. The effect of ageing and immobilization on structure and function of human skeletal muscle fibres. *J Physiol.* 2003;552(Pt 2):499-511.

15. Miller MS, Toth MJ. Myofilament protein alterations promote physical disability in aging and disease. *Exerc Sport Sci Rev*. 2013;41(2):93-99.

16. Thom JM, Morse CI, Birch KM, Narici MV. Influence of muscle architecture on the torque and power-velocity characteristics of young and elderly men. *Eur J Appl Physiol.* 2007;100(5):613-619.

17. Brown WF. A method for estimating the number of motor units in thenar muscles and the changes in motor unit count with ageing. *J Neurol Neurosurg Psychiatry.* 1972;35(6):845-852.

18. Luff AR. Age-associated changes in the innervation of muscle fibers and changes in the mechanical properties of motor units. *Ann N Y Acad Sci.* 1998; 854(1):92-101.

19. Tanaka H, Seals DR. Endurance exercise performance in masters athletes: age-associated changes and underlying physiological mechanisms. *J Physiol.* 2008; 586(1):55-63.

20. Piasecki M, Ireland A, Coulson J, et al. Motor unit number estimates and neuromuscular transmission in the tibialis anterior of master athletes: evidence that athletic older people are not spared from age-related motor unit remodeling. *Physiol Rep.* 2016; 4(19):e12987.

21. Glenn JM, Vincenzo J, Canella CK, Binns A, Gray M. Habitual and maximal dual-task gait speeds among sedentary, recreationally active, and masters athlete late middle-aged adults. *J Aging Phys Act.* 2015;23(3):433-437.

22. Clark BA. Tests for fitness in older adults: AAHPERD Fitness Task Force. *J Phys Ed Rec Dance.* 1989;60(3):66-71.

23. Rikli RE, Jones CJ. The reliability and validity of a 6-minute walk test as a measure of physical endurance in older adults. *J Aging Phys Act.* 1998;6(4):363-375.

24. Jones CJ, Rikli RE, Beam WC. A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Res Q Exerc Sport.* 1999;70(2):113-119.

25. Adell E, Wehmhorner S, Rydwik E. The test-retest reliability of 10 meters maximal walking speed in older people living in a residential care unit. *J Geriatr Phys Ther*. 2013;36(2):74-77.

26. Peters DM, Fritz SL, Krotish DE. Assessing the reliability and validity of a shorter walk test compared with the 10-meter walk test for measurements of gait speed in healthy, older adults. *J Geriatr Phys Ther.* 2013;36(1):24-30.

27. Freire AN, Guerra RO, Alvarado B, Guralnik JM, Zunzunegui MV. Validity and reliability of the short physical performance battery in two diverse older adult populations in Quebec and Brazil. *J Aging Health.* 2012;24(5):863-878.

28. Francis P, Toomey C, Mc Cormack W, Lyons M, Jakeman P. Measurement of maximal isometric torque and muscle quality of the knee extensors and flexors in healthy 50- to 70-year-old women. *Clin Physiol Funct Imaging*. 2016; Epub ahead of print.

29. Choquette S, Bouchard D, Doyon C, Sénéchal M, Brochu M, Dionne IJ. Relative strength as a determinant of mobility in elders 67–84 years of age. A nuage study: Nutrition as a determinant of successful aging. *J Nutr Health Aging.* 2010;14(3):190-195.

30. Dulac M, Boutros GEH, Pion C, Barbat-Artigas S, Gouspillou G, Aubertin-Leheudre M. Is handgrip strength normalized to body weight a useful tool to identify dynapenia and functional incapacity in post-menopausal women? *Braz J Phys Ther.* 2016; Epub ahead of print.

31. Vilaca KH, Alves N, Carneiro JA, Ferriolli E, Lima NK, Moriguti JC. Body composition, muscle strength and quality of active elderly women according to the distance covered in the 6-minute walk test. *Braz J Phys Ther.* 2013;17(3):289-296.

32. Visser M, Goodpaster BH, Kritchevsky SB, et al. Muscle mass, muscle strength, and muscle fat infiltration as predictors of incident mobility limitations in well-functioning older persons. *J Gerontol A Biol Sci.* 2005;60(3):324-333.

33. Hicks GE, Shardell M, Alley DE, et al. Absolute strength and loss of strength as predictors of mobility decline in older adults: the InCHIANTI study. *J Gerontol A Biol Sci.* 2011: 67(1):66-73.

34. Norton C, Toomey C, McCormack WG, et al. Protein supplementation at breakfast and lunch for 24 weeks beyond habitual intakes increases whole-body lean tissue mass in healthy older adults. *J. Nutr.* 2016;146(1):65-69.

35. Francis P, Mc Cormack W, Toomey C, et al. Twelve weeks' progressive resistance training combined with protein supplementation beyond habitual intakes increases upper leg lean tissue mass, muscle strength and extended gait speed in healthy older women. *Biogerontology*. 2016; Epub ahead of print.

36. Greig CA, Young A, Skelton DA, Pippet E, Butler FM, Mahmud SM. Exercise studies with elderly volunteers. *Age Ageing*. 1994;23(3):185-189.

37. Maffiuletti NA, Bizzini M, Desbrosses K, Babault N, Munzinger U. Reliability of knee extension and flexion measurements using the Con-Trex isokinetic dynamometer. *Clin Physiol Funct Imaging*. 2007;27(6):346-353.

38. Rikli RE, Jones CJ. Functional fitness normative scores for community-residing older adults, ages 60-94. *J Aging Phys Act.* 1999;7(2):162-181.

39. Lindle RS, Metter EJ, Lynch NA, et al. Age and gender comparisons of muscle strength in 654 women and men aged 20-93 yr. *J Appl Physiol* (1985). 1997;83(5):1581-1587.

40. Lynch NA, Metter EJ, Lindle RS, et al. Muscle quality. I. Age-associated differences between arm and leg muscle groups. *J Appl Physiol* (1985). 1999;86(1):188-194.

41. Buchner DM, Larson EB, Wagner EH, Koepsell TD, de Lateur BJ. Evidence for a non-linear relationship between leg strength and gait speed. *Age Ageing.* 1996;25(5):386-391.

42. Packard CJ, Bezlyak V, McLean JS, et al. Early life socioeconomic adversity is associated in adult life with chronic inflammation, carotid atherosclerosis, poorer lung function and decreased cognitive performance: a cross-sectional, population-based study. *BMC Public Health*. 2011;17;11(1):42.

Table 1. Summary of Demographics of Adult Participants.

Demographic	50 – 59y (n=71)	60 -70y (n=88)
Age, y	55.4 (4.8) 54.4 – 57.3	64.4 (5.0) 62.9 – 65.3
Height, cm	163.3 (10.9) 161.8 – 166.4	164.2 (9.7) 162.0 – 165.7
Body Mass, kg	70.0 (22.4) 65.4 – 75.5	68.2 (17.4) 66.1 – 72.0
BMI, kg/m^2	26.0 (5.3) 25.3 – 26.9	25.3 (4.7) 24.5 – 26.2

Table 3. Age-related Difference in Peak Torque (PT)/Body Mass (BM) and Functional Performance in Healthy 50 – 70 year Adults.

Age Range, y	PT/BM, N·m/kg	Habitual Gait Speed (10m), m/s	Maximal Gait Speed (10m), m/s	Chair Rise Time (5x), s	Extended Gait Speed (900m), m/s	Chair Rise (30s), n
50 – 59	**n=71**	**n=37**	**n=37**	**n=71**	**n=71**	**n=33**
	1.5 (0.5) 1.4 – 1.6	1.52 (0.2) 1.46 – 1.56	1.84 (0.18) 1.78 – 1.90	8.2 (2.6)* 7.5 – 8.5	2.56 (0.62) 2.42 – 2.70	16.4 (3.5) 15.2 – 17.6

Values are reported as median (IQR), 95% Bootstrap CI.

Table 2. Reliability of Estimate for Functional Performance Measures in Adults Aged 50-70 Years.

Test	Day 1 Mean (SD)	Day 2 Mean (SD)	ICC (95% CI)	*% Difference (*P*-value)
Habitual Gait Speed (10m), m/s	1.4 (0.2)	1.5 (0.2)	0.714 (0.578 - 0.812)	4.3 (P<0.001)
Maximal Gait Speed (10m), m/s	1.8 (0.2)	1.8 (0.2)	0.767 (0.650 - 0.812)	1.7 (P=0.36)
Chair Rise Time (5x), s	9.3 (2.0)	8.7 (1.8)	0.795 (0.691 - 0.867)	-6.5 (P<0.001)
Chair Rise (30s), n	15.5 (3.7)	17.5 (4.4)	0.823 (0.747 - 0.877)	12.9 (P<0.001)
Extended Gait Speed (900m), m/s	2.60 (0.54)	2.68 (0.59)	0.880 (0.811 - 0.925)	3.1 (P=0.028)

*% difference calculated from the differences obtained from the paired sample t-test.

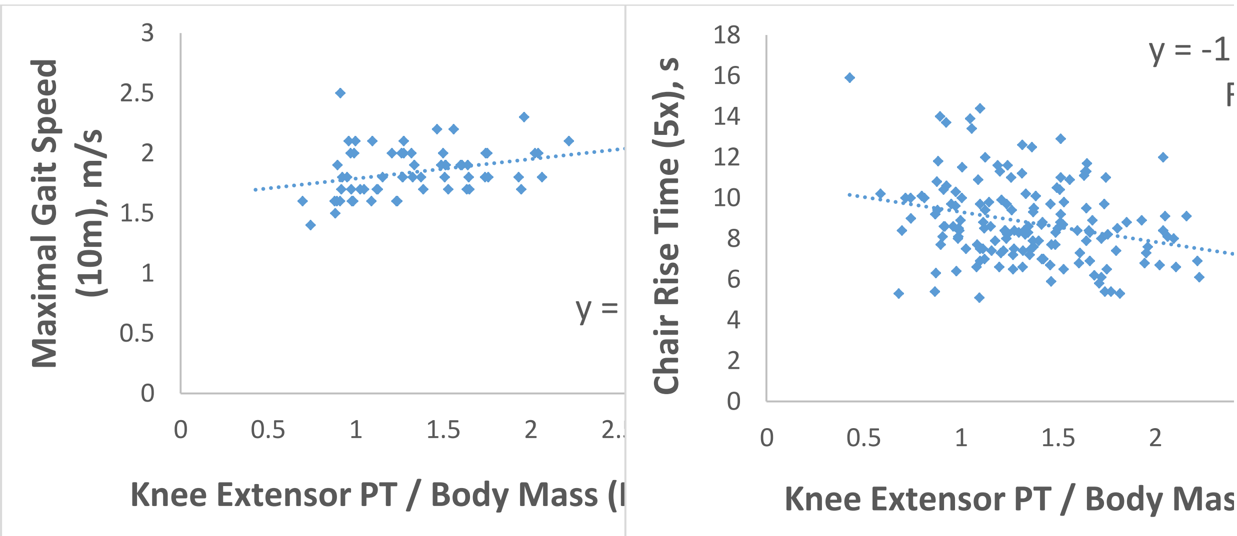
60 – 70	n=88	n=28	n=28	n=88	n=88	n=58
	1.3 (0.3) 1.2 – 1.4	1.40 (0.30) 1.40 – 1.50	1.85 (0.23) 1.77 – 1.94	8.8 (2.5)* 8.4 – 9.4	2.27 (0.45) 2.17 – 2.36	14.0 (5.0)* 13.5 – 15.0
Difference	0.2 0.1 – 0.3	-0.12 -0.02 – 0.14	0.01 -0.11 – 0.09	0.6 0.2 – 1.4	0.29 0.12 – 0.46	-2.4 -0.1 – 3.1
Difference (%)	14.2% *P*=0.001	-7.9% *P*=0.095	0.5% *P*=0.856	7.3% *P*=0.008	11.3% *P*=0.001	14.5% *P*=0.028

Values are reported as mean (SD), median (IQR)*, 95% or Boostrap 95% CI, difference (mean or median, 95% CI) and % difference, *P*-value. **50 – 59y:** Male = 11 (900m, 5 times chair rise). 7 (10m gait Speed). 4 (30-second chair rise). **60 – 70y:** Male = 18 (900m, 5 times chair rise). 5 (10m gait Speed). 13 (30-second chair rise).

Table 4. The Association between Peak Torque (PT)/Body Mass (BM) and Functional Performance in Adults Aged 50-70 Years.

Habitual Gait Speed (10m)	Maximal Gait Speed (10m)	Chair Rise Time (5x)	Extended Gait Speed (900m)	Chair Rise (30s)
0.360 (0.122 - 0.581)	0.329 (0.089 - 0.553)	-0.297 (-0.146 - 0.447)	-0.537 (-0.404 - 0.670)	0.226 (0.021 - 0.428)
P= 0.003	*P*= 0.008	*P* <0.001	*P* <0.001	*P*=0.031

Values are reported as Pearson's r (95% confidence interval) and *P*-value. 10m gait speed, n=65; 5 x chair rise time and 900m gait speed, n=159; 30-second chair rise, n=91.



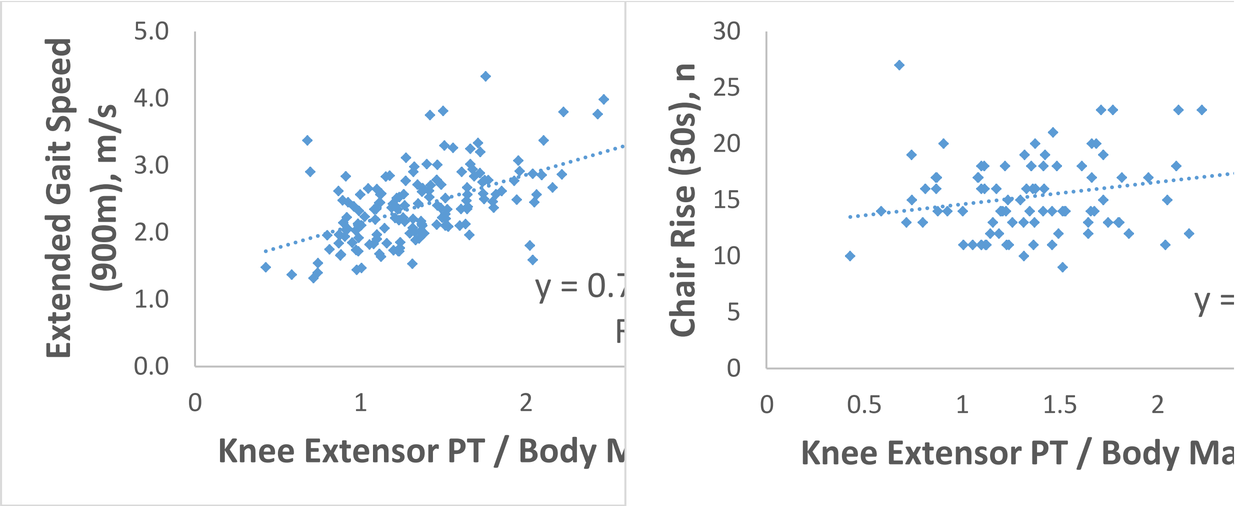


Figure 1. The relationship between knee extensor peak torque (PT) normalized for body mass and functional performance measures in healthy 50 – 70 year old adults.