Walking Speed: A Factor in the Physical Fitness of the Elderly

Andro Štefan, Lovro Štefan, Mario Kasović

Faculty of Kinesiology, University of Zagreb, Croatia

ABSTRACT

The main purpose of the study was to explore whether gait velocity predicts the level of separate and overall physical fitness. In this study, we asked one hundred and twenty older adults over the age of 60 (mean ± SD age 71 ± 7 38 years, height 159 ± 21 cm, weight 70 ± 13 kg) to complete a Senior Fitness Test battery to assess the level of physical fitness and walked across the Zebris pressure platform (Munich, Germany) to measure gait velocity. To calculate overall physical fitness, we summed z-score values of each physical fitness test. Pearson's coefficient (r) was used to determine the level of correlation and coefficient of determination (r2) for variance explained between gait velocity and physical fitness. Respondents conducted a battery of six tests: "chair stand in 30 s", "arm curl in 30 s", "2–minute step test", "chair sit-and-reach test", "back scratch test" and "8-feet up-and-go test". Gait velocity was significantly correlated with chair stand in 30 sec ($r = 0.45$, $r^2 = 20\,\%$, $p < 0.001$), arm curl in 30 sec ($r = 0.56$, $r^2 = 31\,\%$, $p < 0.001$), 2-minute step test ($r = 0.44$, $r^2 = 19\,\%$, $p < 0.001$), chair sit-and-reach test ($r = 0.46$, $r^2 = 21\,\%$, $p < 0.001$), back scratch test ($r = 0.30$, $r^2 = 9\,\%$, $p < 0.001$) and 8-feet up-and-go test ($r = -0.23$, $r^2 = 5\,\%$, $p = 0.011$). Gait velocity was not significantly correlated with waist circumference ($r = 0.12$, $r^2 = 1\%$, $p = 0.189$). Overall physical fitness was strongly correlated with gait velocity ($r = 0.75$, $r^2 = 56\,\%$, $p < 0.001$). In conclusion this study shows that gait velocity may be an easy and quick screening tool to predict the level of separate and overall physical fitness in a sample of older adults.

Keywords: elderly, speed, performance, correlation, tool

INTRODUCTION

Population of older adults aged ≥60 years has increased by 2% in the last 50 years, and it has been estimated that the percentage will increase up to 20% by 2050[1]. Studies have shown that older adults suffer from twice as many disabilities and four times as many physical limitations as people aged < 60 years[2]. It has been-well documented, that aging is associated with many health-related consequences, including cardiovascular[3], metabolic[4] and musculoskeletal[5] diseases and overall mortality[6]. The key of successful aging represents functional independence and maintaining high quality of life[7]. Physical performance deteriorates by age, which is a strong predictor of the aforementioned aging goals[8]. In older adults, the most common way to engage in regular physical activity is walking[9]. Biomechanical parameters of walking in elderly significantly change through reduced speed gait, often accompanied by a reduction in step length and an increment in the time spent in double limb support[10]. As like physical performance, preferred gait speed has been associated with health effects, including lower risk of falls and reduced risk of all-cause mortality[11]. In population-based studies, objective measurement of physical fitness is often time-consuming and cost much. Since gait speed is a quick and valid predictor of the health of the older adults[6,7], it is speculated that such measure may also be a significant predictor of physical fitness. According to the literature, only a handful of studies have examined the associations between gait velocity and physical fitness in older adults[7, 12–14]. Specifically, Ferrucci et al.[12] showed that walking speed was linearly associated with knee extensor strength over the entire range of strength. Another two studies showed similar results, where the gait time decreased linearly with increasing knee extensor strength[13] and strength measure (composed of sum of knee extension, knee flexion and ankle dorsiflexion muscle strength scores) was the strongest predictor of six-meter walking speed[14]. Finally, a study by Ciprandi et al.[7] showed that only hand grip strength was significantly associated with gait stability. In clinical practice, gait speed is often assessed through a few functional mobility and balance scales, including Self Paced Walking Test[15], The Timed Up and Go Test[16] and The Physical Performance and Mobility Examination Test[17]. Although easy to perform, more objective measures, like pressure platform, may be a more reliable and valid instrument to assess gait velocity. Available evidence suggests that no study has explored the association between gait velocity using pressure platform and physical fitness in older adults. Therefore, the main objective of the study was to explore whether gait velocity predicts the level of separate and overall physical fitness in a sample of older adults.

MATERIALS AND METHODS

Study participants:

In this cross-sectional study, we recruited older adults ≥ 60 years from five neighborhoods in the city of Zagreb. At the first stage, we spread the information about the main aims and benefits of the study via posters. At the second stage, 210 participants agreed to join the study. Of these, 73 did not provide full data and 17 could not be longer in the study, due to personal issues. Finally, we based our study on 120 older women (100%). Based on previous studies18, the inclusion criteria were: (1) being ≥ 60 years old, (2) living independently in the community, (3) passed the Short Portable Mental Status Questionnaire[19], (4) be able to ambulate for at least 10 m with or without an aid, (5) being free from neurological diseases, and (6) could arrange their own transport to a testing venue in their community. All participants had given a written informed consent before entered the study. All procedures performed in this study were anonymous and according to Declaration of Helsinki, also approved by the Faculty of Kinesiology, University of Zagreb, Croatia.

Dynamic plantar pressure:

To assess the level of plantar pressure under each participant's feet while walking, we used Zebris plantar pressure platform (FDM; GmbH Munich, Germany; number of sensors: 11.264; sampling rate: 100 Hz; sensor area: 149 × 54.2 cm). According to previous studies, the calibrated platform was placed on a firm, level surface, with a custom-designed dense walkway surrounding the plate to provide a level walking surface18. Each participant was instructed to walk at a comfortable speed across the platform without shoes and socks. Also, all participants were required to look straight forward, not targeting the pressure platform. When they reached the end of a walkway, they needed to turn around for 180° and continue to walk again over the platform. Finally, when they reached the end of a second walkway (trial), they again turned around for 180° and walked final time across the platform till the end of a walkway. Previous evidence has suggested that collecting 3–5 trials across the pressure platform is more reliable in populations affected with diseases, such as arthritis[20]. If we noticed that the participant had targeted the pressure platform or had obvious gait deviations, trials were discarded and we repeated the measurement. Zebris software generated the data regarding the gait velocity in km/h.

Physical fitness:

Senior Fitness Test was used to assess the level of physical fitness[21]. It is composed of 6 tests as follows: (1) chair stand in 30 sec, (2) arm curl in 30 sec, (3) 2 – minute step test, (4) chair sit – and – reach test, (5) back scratch test and (6) 8 - feet up – and – go test. In addition, we measured waist circumference between the last rib and umbilicus and entered it in the model. Chair stand in 30 sec was used to assess lower body strength and participants needed to come to a full stand from a seated position with arms folded across the chest. Arm curl in 30 sec was the second test representing a general measure of upper – body strength and involved counting the number of times a person could curl a hand weight (5 pounds or 2.3 kg for women and 8 pounds or 3.6 kg for men) through a full range of motion. The third test included a person stepping in place and raising the knees to a height halfway between the patella (knee cap) and iliac crest (front hip bone). This test was a measure of aerobic endurance. Next, chair sit – and – reach test aimed to assess lower – body flexibility. The test involved sitting at the front edge of a stable chair with one leg extended and the other foot flat on the floor. With hands on top of each other and arms outstretched, the participant reached as far forward as possible toward the toes. The score was expressed in cm (higher score was better) and was measured 3 times, where the best score was taken in the model. The purpose of the back scratch test was to assess upper-body flexibility, particularly shoulder flexibility. The test involved reaching one hand over the shoulder and down the back as far as possible and the other hand around the waist and up the middle of the back as far as possible, trying to bring the fingers of both hands together. The score was expressed in cm (higher score was better) and was measured 3 times, where the best score was taken in the model. Finally, 8- feet up–and-go test had the purpose to assess agility and dynamic balance. The test involved getting up from a seated position and walking as quickly as possible around the cone that is 8 feet (2.4 m) away and returning to the seated position. The test was performed 2 times and the result was expressed in sec. In addition, we objectively measured height and weight (using Seca portable stadiometer and scale) and asked the participants about their chronological age.

Foot pain:

Presence of foot pain was determined according to previously used question: "On most days do you have pain, aching, or stiffness in either of your feet?"22. Responses were: (1) 'No'; (2) 'Yes, left foot only'; (3) 'Yes, right foot only'; (4) 'Yes, both feet'; (5) 'Yes, not sure what side' and (6) 'Unknown'. For this analysis, responses 'Yes, left foot only', 'Yes,right foot only', 'Yes, both feet and 'Yes, not sure what side' were collapsed into 'Yes' vs. 'No' category. Of note, none of the participants responded with 'Unknown' response.

Data analysis:

Basic descriptive statistics are presented as mean ± SD or median (25th–75th percentile range) for normally and not normally distributed variables. We calculated z–score for each physical fitness test. To get overall physical fitness score, we summed all z–scores. The correlations between all physical fitness components and overall physical fitness with gait velocity were examined by using Pearson's and Spearman's coefficient of correlation (r). To get the shared variance explained between the two variables, we calculated coefficient of determination (r^2). All analyses were performed in Statistical Packages for Social Sciences (SPSS Inc., Chicago, Illinois, USA) with statistical significance of $p < 0.05$.

RESULTS

Basic descriptive statistics of the study participants are presented in Table 1. The correlations between gait velocity, separate components of physical fitness and overall physical fitness score are presented in Figure 1 and Figure 2. Gait velocity was significantly correlated with chair stand in 30 sec ($r = 0.45$, $r^2 = 20$ %, $p < 0.001$), arm curl in 30 sec ($r = 0.56$, $r^2 = 31$ %, $p < 0.001$), 2-minute step test ($r = 0.44$, $r^2 = 19$ %, $p < 0.001$), chair sit-and-reach test ($r = 0.46$, $r^2 = 21$ %, $p < 0.001$), back scratch test ($r = 0.30$, $r^2 = 9$ %, $p < 0.001$) and 8-feet up-and-go test ($r = -0.23$, $r^2 = 5$ %, $p = 0.011$). Gait velocity was not significantly correlated with waist circumference ($r = 0.12$, $r^2 = 1$ %, $p = 0.189$). Overall physical fitness was strongly correlated with gait velocity ($r = 0.75$, $r^2 = 56$ %, $p < 0.001$). When we adjusted for foot pain, similar significant correlations between gait velocity, separate components of physical fitness and overall physical fitness score remained significant.

Table 1. Basic descriptive statistics of the study participants (N=120)

Study variables	mean ± SD
Age (years)	71 ± 7
Height (cm)	159 ± 21
Weight (kg)	70 ± 13
Waist circumference (cm)	91 ± 12
Chair stand in 30 sec (#)	17 ± 4
Arm curl in 30 sec (#)	19 ± 5
2-minute step test (#)	170 ± 44
Chair sit–and-reach test (cm)*	7 (1 - 11)
Back scratch test (cm)*	0.8 (-8 - 4)
8-feet up–and-go test (sec)	5 ± 1
Overall physical fitness (z-score)*	-1 (-2 – 1)
Gait velocity (km/h)	3 ± 1
Foot pain (Yes/No, %)**	53/47

*denotes using median (25th-75th percentile range)

**denotes using percentage (%)

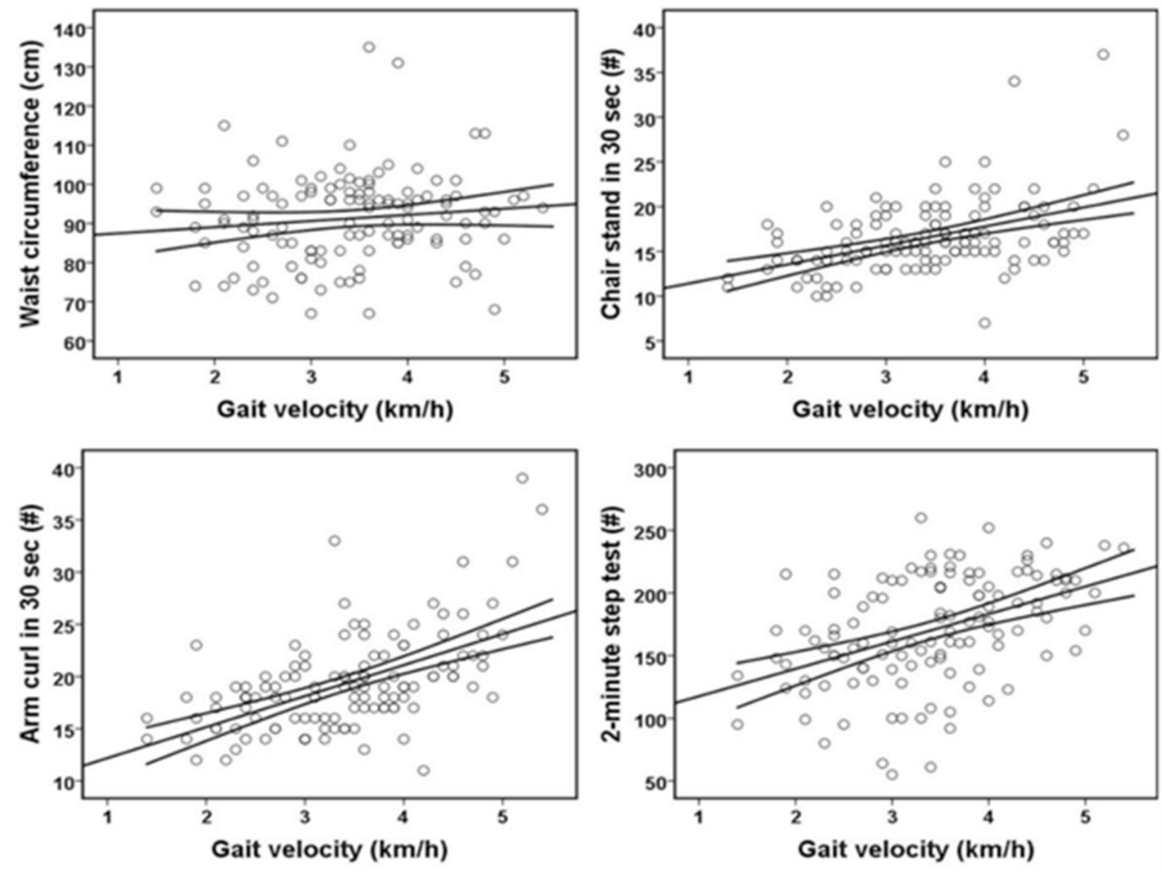

Figure 1. The correlations between gait velocity and waist circumference, chair stand in 30 sec, arm curl in 30 sec and 2-minute step test (N=120).

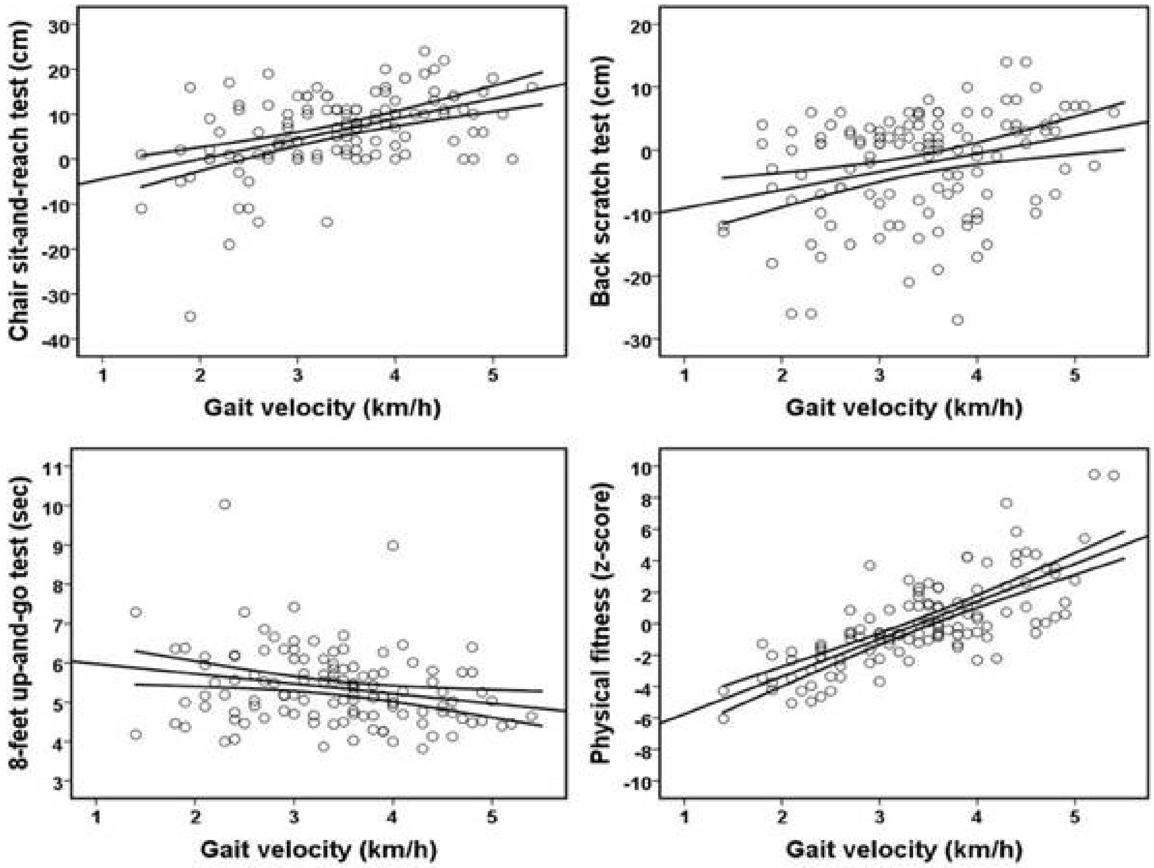

Figure 2. The correlations between gait velocity and chair sit-and-reach test, back scratch test, 8-feet up-and-go test and overall physical fitness (N=120).

DISCUSSION

The main objective of the study was to explore whether gait velocity predicts the level of separate and overall physical fitness in a sample of older adults. Our main findings were: (1) gait velocity was significantly correlated with all physical fitness components ($p < 0.001$), except with waist circumference and (2) gait velocity was strongly correlated with overall physical fitness. Our results are in line with previous cross-sectional studies conducted among older adults[7],12–14. In brief, evidence showed that walking speed was associated with knee extensor strength over the entire range of strength. Moreover, gait time decreased linearly with increasing knee extensor strength[13] and strength measure (composed of sum of knee extension, knee flexion and ankle dorsiflexion muscle strength scores) was the strongest predictor of six- meter walking speed[14]. Different to previous evidence, a study by Ciprandi et al.[7] showed that only hand grip strength was significantly associated with gait stability. The same group of authors also showed, that gait variability was significantly and negatively correlated with the level of physical activity, where participants with moderate gait variability and high preferred walking speed seemed to meet the recommended levels of physical activity[23]. Recently, two longitudinal studies have examined the association between gait velocity and physical performance[24,25]. A prospective cohort study with a follow-up period of 10.5 years showed that gait speed and physical performance independently predicted the risk of all-cause mortality[24], therefore both gait velocity and physical fitness served as significant factors to determine the level of successful aging. Another longitudinal study showed that slow gait was associated with poor physical function, concluding that gait velocity should be a summary index of lifelong aging and potential screening tool for physical and functional decline[25]. Both gait velocity and physical fitness play an important role for maintaining healthy aging process and preserve high quality of life. Previous studies have shown that walking is a most frequent type of exercise among older adults, which requires a significant amount of metabolic energy[23]. This study shows that gait velocity objectively assessed by a pressure platform is a valid instrument to predict the level of physical fitness, especially overall physical fitness. Thus, gait velocity should be implemented in clinical settings as a screening tool to assess physical fitness in older adults. This study has a few limitations. First, by using a cross- sectional design, we cannot conclude the causality of the correlation that is higher levels of physical fitness led to faster gait velocity. Second, we based our findings on a relatively small sample of participants (N = 120), and larger sample size may provide with somewhat different strength of the association. Third, we based our study on a sample living in the urban part of the country, speaking Croatian and only White race. Therefore, future studies should explore longitudinal associations between gait velocity and physical fitness in population-based studies and in different World regions to generate relevant and comparable data. In conclusion, our study shows that gait velocity is moderately correlated with separate components of physical fitness, yet strongly correlated with overall physical index. If gait velocity is used in clinical settings or population-based studies among older adults, results in objectively measured overall physical fitness may be explained by 56% variance of gait velocity.

REFERENCES

Ciprandi, D., Bertozzi, F., Zago, M., Ferreira, C., Boari, G., Sforza, C., & Galvani, C. (2017). Study of the association between gait variability and physical activity. *European review of aging and physical activity: official journal of the European Group for Research into Elderly and Physical Activity*, 14, 19.

Ciprandi, D., Zago, M., Bertozzi, F., Sforza, C., & Galvani, C. (2018). Influence of energy cost and physical fitness on the preferred walking speed and gait variability in elderly women. *Journal of Electromyography and Kinesiology*, 43, 1–6.

Cunningham, D.A., Rechnitzer, P.A., Pearce, M.E., & Donner, A.P. (1982). Determinants of self-selected walking pace across ages 19 to 66. *Journal of Gerontology*, 37, 560–564.

Dominiguez, L.J., & Barbagallo. M. (2016). The biology of the metabolic syndrome and aging. *Current Opinion in Clinical Nutrition and Metabolic Care*, 19, 5–11.

Dufour, A. B., Broe, K. E., Nguyen, U. S., Gagnon, D. R., Hillstrom, H. J., Walker, A. H., Kivell, E., & Hannan, M. T. (2009). Foot pain: is current or past shoewear a factor? *Arthritis and Rheumatism*, 61(10), 1352–1358.

Dumurgier, J., Elbaz, A., Ducimetière, P., Tavernier, B., Alpérovitch, A., & Tzourio, C. (2009). Slow walking speed and cardiovascular death in well functioning older adults: prospective cohort study. *BMJ (Clinical research ed.)*, 339, 4460.

Ferrucci, L., Guralnik, J.M., Buchner, D., Kasper, J., Lamb, S.E., Simonsick, E.M., Corti, M.C., Bandeen-Roche, K., & Fried, L.P. (1997). Departures from linearity in the relationship between measures of muscular strength and physical performance of the lower extremities: the Women's Health and Aging 288 Study. *Journal of Gerontology A Biological Sciences and Medical Sciences*, 52, 275–285.

Himann, J.E., Cunningham, D.A., Rechnitzer, P.A., & Paterson, D.H. (1988). Age-related changes in speed of walking. *Medicine and Science in Sports and Exercise*, 20, 161–166.

Kwon, I., Oldaker, S., Schrager, M., Talbot, L.A., Fozard, J.L., & Metter, E.J. (2001) Relationship between muscle strength and the time taken to complete a standardized walk-turn walk test. *Journal of Gerontology A Biological Sciences and Medical Sciences,* 56, 398–404.

Larsson, L., Degens, H., Li, M., Salviati, L., Lee, Y. I., Thompson, W., Kirkland, J. L., & Sandri, M. (2019). Sarcopenia: aging-related loss of muscle mass and function. *Physiological reviews*, 99(1), 427–511.

Lee, I.M., & Buchner, D.M. (2008). The importance of walking to public health. *Medicine and Science in Sports and Exercise*, 40, 512–518.

Mickle, K.J., Munro, B.J., Lord, S.R., Menz, H.B., & Steele, J.R. (2010). Foot pain, plantar pressure, and falls in older people: a prospective study. *Journal of the American Geriatrics Society*, 58, 1936–1940.

Nofuji, Y., Shinkai, S., Taniguchi, Y., Amano, H., Nishi, M., Murayama, H., Fujiwara, Y., & Suzuki, T. (2016). Associations of walking speed, grip strength, and standing balance with total and cause-specific mortality in a general population of Japanese elders. *Journal of the American Medical Directors Association*, 17, 184.

North, B. J., & Sinclair, D.A. (2012). The intersection between aging and cardiovascular disease. *Circulation research*, 110(8), 1097–1108.

Pfeiffer, E. (1975). A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. *Journal of the American Geriatrics Society*, 23, 433–441.

Podsiadlo, D., & Richardson, S. (1991). The timed 'Up & Go': A test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society*, 39, 142–148.

Rasmussen, L., Caspi, A., Ambler, A., Broadbent, J. M., Cohen, H. J., d'Arbeloff, T., Elliott, M., Hancox, R. J., Harrington, H., Hogan, S., Houts, R., Ireland, D., Knodt, A. R., Meredith-Jones, K., Morey, M. C., Morrison, L., Poulton, R., Ramrakha, S., Richmond-Rakerd, L., Sison, M. L., … Moffitt, T. E. (2019). Association of neurocognitive and physical function with gait speed in midlife. *JAMA Network Open*, 2(10), 1913123.

Rikly, C., & Jones, J.C. (2013). *Senior fitness test manual*. 2nd edition. Champaign, IL: Human Kinetics.

Rimmer, J.H. (1994). *Fitness and rehabilitation programs for special populations*. Madison (WI): Brown Benchmark.

Studenski, S., Perera, S., Patel, K., Rosano, C., Faulkner, K., Inzitari, M., Brach, J., Chandler, J., Cawthon, P., Connor, E. B., Nevitt, M., Visser, M., Kritchevsky, S., Badinelli, S., Harris, T., Newman, A. B., Cauley, J., Ferrucci, L., & Guralnik, J. (2011). Gait speed and survival in older adults. *JAMA*, 305(1), 50–58.

Tiedemann, A., Sherrington, C., & Lord, S.R. (2005). Physiological and psychological predictors of 293 walking speed in older community-dwelling people. *Gerontology*, 51, 390–395.

United Nations. (2005). *World population prospects: the 2004 revision*. New York: UN, 261.

Valentine, R. J., Misic, M. M., Rosengren, K. S., Woods, J. A., & Evans, E. M. (2009). Sex impacts the relation between body composition and physical function in older adults. *Menopause (New York, N.Y.)*, 16(3), 518–523.

van der Leeden, M., Dekker, J.H.M., Siemonsma, P.C., Lek-Westerhof, S.S., & Steultjens, M.P. (2004). Reproducibility of plantar pressure measurements in patients with chronic arthritis: A comparison of one-step, two-step, and three-step protocols and an estimate of the number of measurements required. *Foot and Ankle International*, 25, 739–744.

Winograd, C., Lemsky, C., Nevitt, M., Nordstrom, T.M., Stewart, A.L., Miller, C.J., & Bloch, D.A. (1994). Development of a physical performance and mobility examination. *Journal of the American Geriatrics Society*, 42, 743–749.