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The association between social participation and lower extremity muscle strength, balance, and gait speed in US adults

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ABSTRACT

Social participation is associated with healthy aging, and although associations have been reported between social participation and demographics, no published studies have examined a relationship between social participation and measures amenable to intervention. The purpose was to explore the association between self-reported social participation and lower extremity strength, balance, and gait speed. A cross-sectional analysis of US adults ($n = 2291$; $n = 1{,}031$ males; mean ± standard deviation age 63.5 ± 0.3 years) from the 2001–2 National Health and Nutrition Examination Survey was conducted. Two questions about self-reported difficulty with social participation were categorized into limited (yes/no). The independent variables included knee extension strength ($n = 1537$; classified as tertiles of weak, normal, and strong), balance ($n = 1813$; 3 tests scored as pass/fail), and gait speed ($n = 2025$; dichotomized as slow [less than 1.0 m/s] and fast [greater than or equal to 1.0 m/s]). Logistic regression, accounting for the complex survey design and adjusting for age, sex, physical activity, and medical conditions, was used to estimate the odds of limitation in social participation with each independent variable. Alpha was decreased to 0.01 due to multiple tests. Slower gait speed was significantly associated with social participation limitation (odds ratio = 3.1; 99% confidence interval: 1.5–6.2). No significant association was found with social participation and lower extremity strength or balance. The odds of having limitation in social participation were 3 times greater in those with slow gait speed. Prospective studies should examine the effect of improved gait speed on levels of social participation.

1. Introduction

Healthy or active aging has been studied and promoted, with the World Health Organization (WHO) defining active aging as "the process of optimizing opportunities for health, participation, and security in order to enhance quality of life as people age" (World Health Organization, 2002a, p.12). Participation, defined as involvement in a life situation by the International Classification of Functioning, Disability, and Health (ICFDH), is an important component of biopsychosocial models of health and disability (World Health Organization, 2002b). Social participation is one component in the broader category of participation, and has been defined by interpersonal interactions with friends or family, membership in community groups (Minagawa and Saito, 2014) or social interactions in work environments (Hsu, 2007). High social participation and active engagement are often included in the discussion of healthy aging (Fuchs et al., 2013; Bowling and Dieppe, 2005). In fact, social participation, as measured by the SF-36 Social Functioning Scale, was associated with healthy aging in community-dwelling older adults (Wang et al., 2013; Li et al., 2014). Social participation is also a common factor associated with high quality of life in studies of American older people, as well as several European countries (Netuveli, 2006). Since social participation tends to decline with increasing age (Mendes de Leon et al., 2003; Desrosiers et al., 2009), and limited social participation may have negative effects on mortality (Glass et al., 1999), and physical (Mendes de Leon et al., 2003) and cognitive (Krueger et al., 2009) morbidity, it is important to identify means through which social participation might be maintained.

Associations between social participation and demographic characteristics (e.g., sex, marital status) (Mendes de Leon et al., 2003; Desrosiers et al., 2009; Krueger et al., 2009), and healthy behaviors (e.g., physical activity, nutrition) (Wang et al., 2013) have been established. There is, however, a paucity of evidence on the association between physical impairments and mobility deficits and social participation. Previous studies have small sample sizes (Samuel et al., 2012) or assessed strength (Beauchamp et al., 2015) and gait speed (Fairhall et al., 2014) with a more global measure of participation rather than focused analysis of social participation, and no consistent results were reported. Inconsistency in the previous studies, coupled with the lack of

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Abbreviations: NHANES, National Health and Nutrition Examination and Survey; LE, lower extremity; NCHS, National Center for Health Statistics.

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population-based studies identifying relationships between social participation and isolated impairments or mobility deficits, suggest a need for further research.

The purpose of this paper is to explore the association between self-reported social participation and lower extremity strength, balance, and gait speed in order to better understand relationships that may be amenable to intervention. We hypothesized that decreased social participation would be associated with decreased lower extremity muscle strength, standing balance, and gait speed.

2. Methods

2.1. Study design and population

Conducted by the National Center for Health Statistics (NCHS), the cross-sectional National Health and Nutrition Examination Survey (NHANES) uses a stratified, multi-stage, probability design to assess health of American adults and children. Details of NHANES methodology are available at: http://wwwn.cdc.gov/nchs/nhanes/search/nhanes01_02.aspx. NHANES consists of a detailed home interview and examination conducted in a mobile examination center. NHANES continually samples a nationally representative cohort of the US civilian, non-institutionalized population. The present study (analyzed 2015) uses 2001–2 NHANES data from individuals 50 years and older; this was the most recent NHANES data with lower extremity strength and timed walking test. Informed consent was obtained for all participants and the Institutional Review Board of the NCHS approved the protocol prior to data collection.

From a potential sample of 2563 participants age 50 years and older, 2291 completed the interview and appropriate examination components of NHANES. Each examination component had different exclusions (see below under Measurements); participants were also excluded if there was equipment failure, communication problems, mobility problems, or participant refusal. 1487 (64.9%) completed the lower extremity strength testing, 1813 (79.1%) completed the balance testing, and 2025 (88.4%) completed the timed walking test.

2.2. Measurements

NHANES measurements were completed during an interview and an examination. Participants were asked about demographic information, as well as current medical conditions and frequency and duration of moderate or vigorous physical activity, which were assessed as confounders. The medical conditions assessed included pulmonary (i.e., “Has a doctor or other health care professional ever told you that you have and do you still have [asthma], [emphysema], or [chronic bronchitis]?”), cardiac (i.e. “Has a doctor or other health care professional ever told you that you have and do you still have [congestive heart failure], [angina], or [heart attack]?”), musculoskeletal conditions (i.e., “Has a doctor or other health care professional ever told you that you have and do you still have [arthritis] or [osteoporosis]?”), diabetes (i.e., “Other than during pregnancy, have you ever been told by a doctor or other health care professional that you have and do you still have diabetes or sugar diabetes?”), and cancer (i.e., “Have you ever been told by a doctor or other health care provider that you have cancer or malignancy of any kind?”), and were categorized as “yes” or “no.” Participants were further asked about participation in moderate or vigorous physical activity for at least 10 min over the past 30 days, and these 2 questions (i.e., moderate or vigorous) were collapsed into a single variable with “yes” or “no.”

2.3. Social participation

Two questions assessing social participation with leisure activities were phrased to measure the participant's level of difficulty in performing the task without using any special equipment. The questions asked about difficulty “going out to things like shopping, movies, or sporting events,” and “participating in social activities [visiting friends, attending clubs or meetings or going to parties].” The possible answers were Likert-type responses with 4 levels (i.e., ‘No difficulty,’ ‘Some difficulty,’ ‘Much difficulty,’ and ‘Unable to do’). Any participant who answered ‘Some difficulty’ or more with either of these questions was categorized as having limitation with social participation. Those with ‘No difficulty’ with both questions were categorized as no limitation. This is similar to the methods with other studies using the physical functioning measures from NHANES (Ettinger et al., 1994).

2.4. Lower extremity muscle strength

Before testing, participants were screened and excluded if there was a myocardial infarction within the past six weeks, chest or abdominal surgery within the past three weeks, knee surgery or knee replacement surgery, severe back pain, or a history of brain aneurysm or stroke. Knee extension peak torque was assessed using an isokinetic dynamometer (Kin Com, Chattex Corp., Chattanooga, TN). Maximal voluntary concentric muscle force was measured in Newtons in the right leg at a velocity of 1.05 rads/s (60 °/s); previous literature reported no difference in torque between the right and left leg for knee extension (Lindle et al., 1997). Each participant had a total of 6 trials: 3 submaximal trials for warm-up and 3 trials for maximal voluntary effort. The best maximal effort was used as peak force. Peak torque (N-m) was calculated as peak force (N) multiplied by the mechanical arm length (m), i.e., the distance from the ankle to the knee joint. Gravity corrections to peak torque were based on the measured leg weight at 150° (2.62 rads) using the formula by Nelson and Duncan (Nelson and Duncan, 1983). Additional information on the muscle strength testing procedures can be found at: http://www.cdc.gov/nchs/data/nhanes/ms.pdf. Peak torque was normalized to body weight, measured using standard procedures (Lohman et al., 1988) on a scale-mounted stadiometer. Percent of predicted normal strength was calculated using the formula from Neder, et al. (Neder et al., 1999). Due to missing variables for the strength prediction formula, data were available for 1488 (96.8%) of the 1537 who completed strength testing. Strength was then categorized to Weak (<75% of predicted; 0–25th percentile of the distribution), Normal (75–100% of predicted; 25th–75th percentile), and Strong (>100% of predicted, 75th–100th percentile).

2.5. Balance

Balance testing consisted of the modified Romberg Test of Standing Balance on Firm and Compliant Support Surfaces (Weber and Cass, 1993). Participants were excluded from balance testing if there was an inability to stand without external support, current dizziness sufficient to cause unsteadiness, foot or leg amputation, weight over 275 lb or size that was unable to accommodate safety equipment, or visual impairment or other medical contraindication to testing. The balance test examined the participant's ability to stand unassisted with arms folded across the waist using 4 test conditions designed specifically to test the sensory inputs that contribute to balance — the vestibular system, vision, and proprioception. The first condition consisted of standing with the feet together and eyes open, testing all systems contributing to balance. The second condition consisted of standing with the feet together and eyes closed, testing the vestibular system and proprioception. The third condition involved standing on a foam pad with eyes open, testing vision and the vestibular system. The fourth test condition involved standing on a foam pad with eyes closed, testing vestibular function exclusively. The second, third, and fourth conditions were used in these analyses.

Balance testing was scored on a pass/fail basis per the design of the test for NHANES. Passing for condition one and two required maintaining the position for 30 s each; passing for condition three and four required maintaining the position for 15 s each. Failing was defined as arm or foot movement, or examiner intervention to achieve stability or maintain balance, or eye opening (conditions 2 and 4). Up to two trials were allowed for each condition. Because each successive test condition was progressively more difficult, the balance testing ended whenever a participant failed to pass either trial of a test condition; those were counted as failure for subsequent conditions. Of the 1813 who started the balance testing (condition 1), 1808 progressed to condition 2 (i.e., did not fail condition 1), 1718 progressed to condition 3, and 1669 progressed to condition 4. Further details of balance testing procedures are available at: http://www.cdc.gov/nchs/data/nhanes/ba.pdf.

2.6. Gait speed

A timed walk test on a 20 ft (6.15 m) course at the participant's usual speed, measured using a stopwatch, and recorded to the nearest hundredths of a second was conducted. Walk time was measured from the time the participant's foot first touched the floor across the starting line and stopped when the participant's foot touched the floor across the finish line. Timed walking was converted to meters/second. Participants were excluded if a person required assistance with walking; assistive devices (e.g., cane) were allowed. Two participants had usual walking speed more than 4 standard deviations from the mean (2.5 and 3.7 m/s) and were dropped from analysis, resulting in 2023 participants. For this study, gait speed was dichotomized into less than 1.0 m/s and greater than or equal to 1.0 m/s, as speeds greater than or equal to 1.0 m/s suggest healthier aging (Cesari et al., 2005; Viccaro et al., 2011) and predict longer life expectancies (Studenski et al., 2011).

2.7. Statistical analysis

Statistical analyses (SAS Institute, version 9.4, Cary, NC) accounted for the complex survey design used in NHANES. All analyses included survey sample weights, stratum, and primary sampling units per recommendations from NCHS, to address oversampling, non-response, non-coverage, and to provide nationally representative estimates. Logistic regression was used to assess the association between social participation (dependent variable: limited yes or no) and lower extremity strength, balance, and gait speed (independent variables). A distinct model was computed for each independent variable (5 models with 3 for each of the balance test conditions 2–4), and separate assessment of confounding was done for each model. Potential covariates included race/ethnicity, income, living with a partner, moderate and/or vigorous physical activity, and medical conditions (cardiac, pulmonary, and musculoskeletal conditions, cancer, and diabetes) for all models, and age, sex, and body mass index for the models with balance and gait speed as independent variables. A variable was considered a confounder if it was independently associated with the dependent and independent variable. Odds ratios with 99% confidence intervals were estimated with each logistic regression model. Final models included age, sex, physical activity, living with a partner as confounders for all models, and body mass index for balance and gait speed models. All analyses were repeated restricting age to 65 years and older as well as 75 years and older. All statistical testing was 2-sided. Bonferroni's correction was applied due to multiple tests (5 models; $0.05/5 = 0.01$), and alpha was set at 0.01 for all analyses.

3. Results

The overall sample included 2291 participants. Demographics for these participants by level of self-reported limitation with social participation (yes or no) are presented in Table 1. Those with a self-reported limitation with social participation were older and heavier (higher BMI). Additionally, the group of participants with self-reported limitation in social participation were a higher proportion of: females, not living with a partner, physically inactive, and those with a lower income and self-report of a medical condition.

Because of different exclusion criteria for each measurement, the samples were not consistent for each analysis. 1487 participants completed the lower extremity strength testing. After accounting for survey design and weighting for population estimates, with unadjusted analysis, a higher proportion of those classified as weak responded to having a limitation with social participation ($p < 0.0001$) (Table 2). A total of 1813 participants completed the balance testing, and a lower population weighted proportion of those reporting a social participation limitation successfully completed each of the balance tests ($p < 0.0001$ for all conditions), especially with condition 4 (standing on a foam pad with eyes closed; 58.8% vs. 35.2%, respectively). Of the 2025 who completed the timed, walking test, gait speed was slower in those who reported a limitation with social participation, and a lower proportion of those who reported a limitation walked greater than or equal to 1.0 m/s ($p < 0.0001$ for both).

The association between self-reported limitation with social participation and each measurement adjusted for relevant covariates is presented in Fig. 1. Gait speed, dichotomized as slow (less than 1.0 m/s) and fast (greater than or equal to 1.0 m/s), was significantly associated with a report of limitation with social participation (odds ratio [OR] = 3.1 99% confidence interval [CI] 1.5–6.2). That is, those with a reported limitation with social participation had 3 times higher odds of walking slower than 1.0 m/s compared with those without a reported limitation with social participation. No significant association was found with lower extremity strength or balance with adjusted analyses. Analyses were also conducted limiting participants to those over 65 years old as well as those over 75 years old. For lower extremity strength in the sample limited to those 65 and older, the association with strength categories and self-reported limitation with social participation became significant ($p = 0.0014$). Those with self-reported limitation with social participation had a significantly higher odds of being weak compared with strong (OR = 3.5 [99% CI: 1.3–9.9]), but no significantly greater odds with the normal strength compared to strong (OR = 1.4 [99% CI: 0.4–4.5]). For those 75 and older with lower extremity strength testing, and both age group analyses with balance, the results were similar, except wider confidence intervals due to smaller sample sizes. For gait speed, the effect was greater in the 65 and older and even greater in the 75 and older, but precision was reduced (data not shown).

4. Discussion

To our knowledge, this is the first study to show a relationship between social participation and gait speed. Specifically, participants who reported a limitation in social participation had 3 times greater odds of walking slowly, i.e., less than 1.0 m/s. This finding is accordant with previous work that demonstrated an association between participation and slower gait, however participation was measured in multiple domains including mobility (Fairhall et al., 2014). The association between gait and social participation is of particular interest because social participation is associated with mortality (Minagawa and Saito, 2014; Dalgard and Lund, 1998; Holt-Lunstad et al., 2010). In fact, the value of high levels of social participation on survival is of similar magnitude to the effects of smoking cessation on survival (Holt-Lunstad et al., 2010). Social participation is also related to morbidity, with higher levels of social participation related to healthy aging (Holmes and Joseph, 2011; Qin et al., 2015). The results of the current study may raise the question if the ability to walk at a speed greater than or equal to 1.0 m/s may be a factor in maintaining an active social network, but this must be further tested in prospective studies.

Independent of an association between gait speed and social participation, there is strong evidence supporting an association between gait speed and survival. Studenski, et al. (Studenski et al., 2011), pooled the data from 9 cohort studies of community-dwelling older adults and found that walking at speeds of 1.0 m/s or faster is predictive of living longer than what would be expected given one's age and sex. It was proposed that this link has a physiologic basis (Studenski et al., 2011).

Table 1
Weighted characteristics by self-reported social participation: NHANES 2001–2, 50 years and older.

Characteristic	Self-reported limitations with social participation n = 433	No self-reported limitations with social participation n = 1858	Total n = 2291
Age; mean (standard error [SE])*	68.8 (0.66)	62.5 (0.26)	63.5 (0.29)
Sex (%male)*	37.6%	47.5%	45.9%
Race			
Non-Hispanic White	76.8%	80.5%	79.9%
Non-Hispanic Black	9.9%	8.6%	8.8%
Hispanic	11.3%	7.0%	7.7%
Other	1.9%	3.9%	3.6%
Marital status (% living with a partner)*	52.1%	68.7%	66.0%
Income*			
Under $20,000	50.4%	20.1%	25.0%
$20,000–$44,999	31.6%	32.8%	32.7%
$45,000–$74,999	12.0%	21.2%	19.7%
Over $75,000	6.0%	25.9%	22.6%
Body mass index (kg/m^2); mean (SE)*	31.3 (0.46)	28.1 (0.16)	28.5 (0.21)
Medical conditions (% yes)			
Pulmonary condition*	18.0%	9.8%	11.2%
Cardiac condition*	35.1%	14.6%	17.9%
Musculoskeletal condition*	72.3%	38.5%	44.0%
Cancer*	22.5%	16.7%	17.6%
Diabetes*	24.1%	10.6%	12.8%
Physical activity* (% yes)**	34.9%	62.3%	58.7%

NHANES: National Health and Nutrition Examination Survey.

* $p < 0.01$.

** n = 2157 as 136 reported 'Unable to do activity'.

Normal walking speeds require adequate function of the nervous, musculoskeletal, cardiac, and respiratory systems, and as such, gait speed may provide a surrogate measure of overall health. The current study suggests that an additional factor to consider is the relationship of gait speed with social participation. The value of gait speed as a "sixth vital sign" (Fritz and Lusardi, 2009; Studenski et al., 2003; Franklin et al., 2015) may be that it reflects not only physiologic health but also social health, both of which contribute to survival.

In the current study, there was not a significant relationship between social participation and lower extremity muscle strength. This is congruent with a previous report, although in that study, participation was not restricted to social participation (Beauchamp et al., 2015). Conversely, Samuel, et al. reported a significant association between muscle strength and social function, but correlation coefficients for lower extremity muscle groups were modest (0.24–0.32) (Lindle et al., 1997). Due to the inconsistent findings between the current study and previous studies, more empirical evidence is needed to clearly identify the relationship of muscle strength and social participation.

In the current study, social participation was also not related to standing balance. Previous reports supporting a relationship between participation and balance did not focus on social participation, included only participants with stroke, and used the Berg Balance Scale to measure balance (Chen et al., 2015; Hamzat and Kobiri, 2008). Further studies are needed to determine if other standardized tests of balance (e.g., Dynamic Gait Index) are sensitive to levels of social participation in healthy adults.

Gait speed can be improved with therapeutic exercise and gait training (VanSwearingen et al., 2011; Lopopolo et al., 2006). Even small increases of 0.1 m/s to 0.2 m/s can improve survival (Studenski et al., 2011), and reduce the risk for disability (Perera et al., 2016). The potential impact of physical interventions and improved gait speed on social participation provides further support for identifying those with slow gait and initiating treatment. Although beyond the scope of this paper due to cross-sectional design, it is reasonable to suggest that gains in gait speed may result in increases in social participation, however this needs to be empirically tested.

4.1. Limitations

Because of the lack of temporality with cross sectional data, conclusions about causation and the precipitating factors are limited. Furthermore, with an analysis of an existing national database, this study was not designed to examine why social participation is related to gait speed. Minimum gait speeds of 0.8 m/s have been used to identify the ability to ambulate in the community (Fritz and Lusardi, 2009). We chose a cut-off of 1.0 m/s to distinguish successful aging based on work by Cesari and colleagues (Cesari et al., 2005). Participants in the current dataset were 50 years of age and older. We did not restrict our

Table 2
Weighted unadjusted gait speed, lower extremity strength, and balance by level of self-reported social participation, NHANES 2001–2**.

Variable	Self-reported limitation with social participation	No self-reported limitation with social participation	Total
Lower extremity muscle strength*			
Weak	46.1%	21.8%	24.2%
Normal	34.5%	53.1%	51.3%
Strong	19.4%	25.1%	24.5%
Balance: Modified Romberg			
% Passed Condition 2	92.8%	98.1%	97.5%
% Passed Condition 3	89.6%	97.5%	96.6%
% Passed Condition 4*	35.2%	58.8%	56.1%
Gait speed (m/s); mean (SE)*	0.77 (0.02)	1.08 (0.008)	1.03 (0.008)
% Greater than 1.0 m/s*	20.5%	65.3%	58.8%

* = <0.0001.

** Adjusted for sample weights to estimate population estimates.

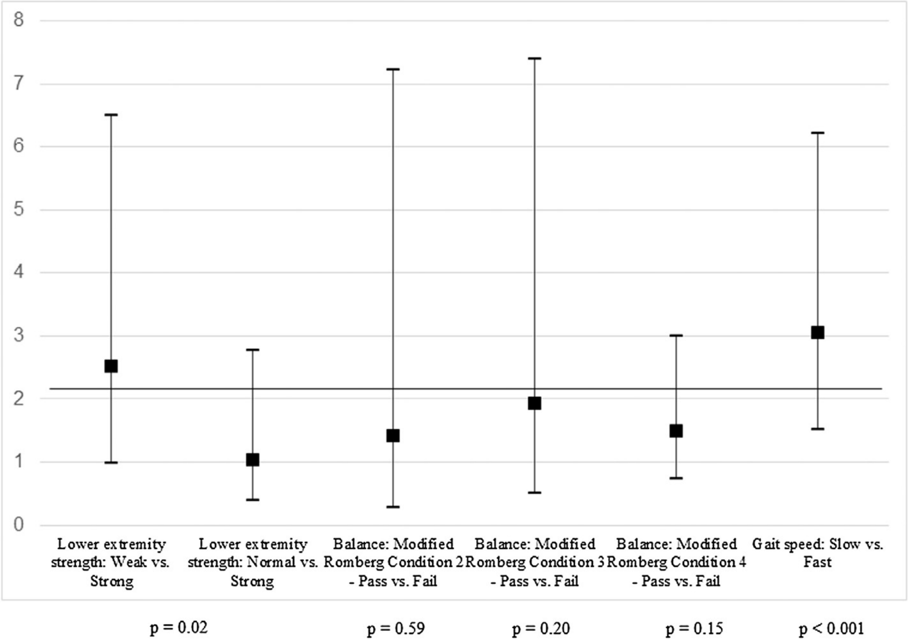

Fig. 1. Adjusted odds ratios with 99% confidence intervals for each independent variable with limitations with social participation, NHANES 2001–2.

analysis to only the elderly limiting comparisons with other reports that included only those 65 years and older. As with any observational study design, residual confounding cannot be ruled out, and assessment of confounding was limited to the variables collected in NHANES. Although NHANES collected information on demographic (e.g., age, sex, race/ethnicity, income), clinical (e.g., height, weight) and behavioral (e.g., physical activity) factors, a more complete assessment of all potential determinants of health and social participation (e.g., poverty, urban/rural, access) was not possible. These data were collected in 2001–2 and the assessment of social participation may be limited due to the questions asked. This was the only time NHANES measured gait speed and lower extremity strength. Some of the variables had missing values, either due to exclusions for the testing (e.g., unable to walk independently for gait speed). Sensitivity analyses were completed to assess odds of missing/exclusion with each independent variable. For each independent variable, those who were excluded or had testing issues had a significantly higher proportion of people with a self-reported social participation limitation compared with people who completed the test (gait speed: 35% vs. 17%, lower extremity muscle strength: 34% vs. 11%; and balance: 41%% vs. 13%; all $p < 0.001$). These were not unexpected given the nature of the reasons for exclusions for each test (e.g., assist with walking for gait speed, severe back pain for lower extremity strength testing, and inability to stand without support for balance testing). Those with missing values for the independent variables tended to be older, sedentary, and have more medical conditions. The strength of this study is the large, population-based size and stratified random sampling, increasing the external validity.

5. Conclusion

In summary, our results demonstrate that there is an association between social participation and gait speed. Using 1.0 m/s as a cut-off for healthy aging, we found that the odds of lower self-reported social participation limitations had 3 times greater odds of a slower walking speed. Gait speed can be increased with physical interventions, particularly one based on principles of motor sequence learning (VanSwearingen et al., 2011). Further evidence is needed to determine if improved gait speeds are associated with increased levels of social participation and concomitant reductions in morbidity and mortality.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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Transparency document

The transparency document associated with this article can be found, in online version.

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