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Title

Duration of moderate to vigorous daily activity is negatively associated with slow walking speed independently from step counts in elderly women aged 75 years or over: A cross-sectional study

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Abstract

Objectives: This study aimed 1) to examine whether objectively measured duration of moderate to vigorous physical activity (MVPA) was associated with slow walking speed, independent from step counts, in elderly women aged 75 or over (old-old) and 2) to determine a possible cut-off value for duration of MVPA related to slow walking speed.

Methods: Participants were 350 community-dwelling old-old women. Slow walking speed was defined as usual walking speed <1.0 m/sec. Duration of MVPA (activity at an intensity >3 metabolic equivalents) and number of step counts were measured using a uniaxial accelerometer over 1 wk. Body mass index, grip strength, back and leg pain, cognitive function, executive function, and presence of depression were also assessed. Participants with missing data were excluded from the main analysis.

Results: The mean age of the participants was 79.9±3.6 y. The prevalence of slow walking speed was 14.9%. Multiple logistic regression analysis showed that the duration of MVPA was significantly and inversely associated with slow walking speed, independent from step counts and other confounding

factors (adjusted odds ratio = 0.94 per 1 min/d increment, 95% confidence interval = 0.73-0.99; p = 0.031). This relationship was also observed in sensitivity analysis that included all participants. A MVPA cut-off value of 8.7 min/d was determined using the receiver operating characteristic analysis.

Conclusion: The findings from the present study suggest that promoting MVPA may be helpful to prevent slow walking speed. The validity of MVPA for predicting slow walking speed needs to be confirmed in future prospective studies.

Key words: physical activity, walking speed, community-dwelling elderly people

1. Introduction

Walking speed declines with aging (Auyeung, Lee, Leung, Kwok, & Woo, 2014) and slow walking speed predicts adverse health outcomes such as falls (Montero-Odasso et al., 2005), disability (Shinkai et al., 2000), and mortality (Studenski et al., 2011). In addition, walking speed is a reliable (Peters, Fritz, & Krotish, 2013) and easily evaluated parameter in the clinical setting. Consequently, walking speed has been recommended as a useful clinical indicator, and is sometimes considered a vital sign for the care of elderly people (Cummings, Studenski, & Ferrucci, 2014). The prevalence of physical frailty in community-dwelling elderly people is high especially in elderly women aged 75 years or over (hereafter referred to as "old-old") (Collard, Boter, Schoevers, & Oude Voshaar, 2012). Therefore, early detection of slow walking speed in this population may provide key information for health promotion.

In addition to aging, walking speed is associated with sensorimotor function (Tiedemann, Sherrington, & Lord, 2005), psychological functions (Tiedemann et al., 2005), as well as habitual physical activity (PA) (Aoyagi,

Park, Watanabe, Park, & Shephard, 2009). PA has been reported as a predictor of disability in activities of daily living (Tak, Kuiper, Chorus, & Hopman-Rock, 2013). Additionally, a randomized controlled trial by Pahor et al. recently reported that a structured moderate-intensity PA program, compared with a health education program, reduced major mobility disability. Mobility disability was defined as the inability to complete a 400-m walk test within 15 min without sitting and without the help of another person or walker (Pahor et al., 2014). Thus, promotion of PA can also be effective in maintaining or improving walking speed and potentially over all long-term health.

Although the relationship of PA to walking speed has been well documented (Brach et al., 2003; Busch et al., 2015; De Pew, Karpman, Novotny, & Benzo, 2013; Haight, van der Laan, Manini, & Tager, 2013; K. Kwan et al., 2014), there is a lack of evidence in old-old women, who have a higher risk of frailty compared to men or younger individuals (Collard et al., 2012). Additionally, these previous studies did not consider confounding factors of PA and walking speed such as muscle strength or presence of

depression. Furthermore, it remains unknown whether moderate to vigorous PA (MVPA) is beneficial for promoting health in old-old women. Duration of habitual MVPA (i.e., brisk walking, stepping up stairs, and aerobics) is a representative measure of PA intensity and is generally defined as activity at an intensity > 3 metabolic equivalents (METs) (Ainsworth et al., 2011; Aoyagi & Shephard, 2010). MVPA has beneficial effects for reducing risks of cardiovascular disease and all-cause mortality (Bucksch, 2005; Tanasescu et al., 2002). In elderly people aged 65 years or over, MVPA has been reported to have a stronger negative correlation with loss of lean body mass than step counts (Shephard, Park, Park, & Aoyagi, 2013). This evidence suggests that promoting MVPA is likely to have more benefits than merely increasing steps counts for health promotion in elderly people. However, there has been little research on the relationship between duration of habitual MVPA and slow walking speed in old-old women.

Therefore, the primary purpose of this study was to examine whether objectively measured duration of habitual MVPA was associated with slow walking speed, independent from confounding factors among old-old women.

If so, we aimed to determine a possible cut-off value for duration of MVPA related to slow walking speed, which was defined as usual walking speed < 1.0 m/sec.

2. Methods

2.1. Study design and participants

This cross-sectional study was a secondary investigation from a prospective cohort study conducted by our laboratory at the Graduate School of Medicine at Nagoya University in Japan. The inclusion criterion of the cohort study was community-dwelling old-old people. The study protocol was approved by the Ethics Committee of the School of Health Sciences at Nagoya University (approval number 2012-0131). The cohort study recruited community-dwelling volunteers via mail, and a total of 428 elderly people provided written informed consent to participate. For the present study, we enrolled 350 old-old women who could walk independently without any walking assistance. No participants had any severe cardiac, pulmonary, musculoskeletal, or neurological disorders.

2.2. Assessment of slow walking speed

A 14-m walkway was used to measure usual walking speed. Usual walking speed was calculated over a 10-m distance between the 2- and 12-m marks of the 14-m walkway (Liu-Ambrose, Pang, & Eng, 2007). The test was performed twice, and the faster result was used as the index of usual walking speed. Slow walking speed was defined as usual walking speed < 1.0 m/sec according to an epidemiological study of Japanese community-dwelling elderly people (Shimada et al., 2013).

2.3. Assessment of PA

PA was measured in autumn (September to November) in order to avoid seasonal effects. MVPA and step counts were measured using a uniaxial accelerometer (Kenz Lifecorder, Suzuken Co., Ltd., Nagoya, Japan). The device records step counts and intensity of PA. The intensity of PA was categorized into 11 levels (0, 0.5, 1-9) based on the recorded acceleration pattern.

A previous study assessed the relationship between these accelerometer levels and METs determined using objectively measured oxygen consumption during walking on a treadmill in young men (Kumahara et al., 2004). The study revealed that an accelerometer level > 4 corresponded to > 3 METs. Since metabolism is lower in the elderly compared to young adults (M. Kwan, Woo, & Kwok, 2004), the oxygen consumption may also be lower in the elderly. Yet, even if an accelerometer level > 4 corresponded to < 3 METs in the elderly, the relative intensity of the activity > level 4 is actually higher in the elderly due to their lower fitness level. Therefore, the accelerometer level > 4 in the elderly is likely to be appropriate as an indicator of MVPA. To date, PA with an acceleration level > 4 from this device has been widely used to categorize MVPA in middle aged and elderly adults (Aoyagi et al., 2009; Hara et al., 2016; Nicklas et al., 2016).

All of the participants were instructed to wear the accelerometer at the waist all day with the exception of bathing and sleeping, for seven consecutive days to assess daily PA. We defined daily PA measured for seven

days as habitual although there is not sufficient consensus about the definition of habitual PA. Moreover, participants were asked to continue their normal activities of daily living during the measurement period, and were blinded to their measured values. The mean duration of MVPA and the mean number of daily step counts were calculated.

2.4. Physical and psychological factor

As the physical factor, we assessed body mass index (BMI), grip strength, and presence of leg or back pain. BMI was calculated as weight divided by the square of height. Body weight was measured using a digital weight scale and height was measured using a stadiometer. Grip strength was measured with the Jamar dynamometer (Sammons Preston, Bolingbrook, IL, USA) set at the second handle position. The participants sat with the wrist in a neutral position and the elbow flexed at 90°. Grip strength was measured twice for each hand, and the highest value was used as the index of grip strength. Each participant self-reported presence of pain in the back or leg as “none,” “sometimes,” or “always.” Presence of pain for

data analysis in this study was defined as the participant feeling pain "sometimes" or "always."

As the psychological factor, we assessed cognitive state, executive function and depression using the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975), Trail Making Test (TMT) (Reitan, 1958), and 5-item Geriatric Depression Scale (GDS-5) (Hoyl et al., 1999), respectively. MMSE is a standard test to assess global cognitive function that includes 11 questions with a maximum score of 30. TMT is a visual task in which participants are asked to draw a line from one point to the next as quickly as possible in order to connect circles in numerical order (part A) and in alternating order between numerical and Japanese characters (part B). The time to finish each part was recorded and the difference between part B and A (ΔTMT) was calculated (Hirota et al., 2010). GDS-5 is a questionnaire to assess depression symptoms using five items. A GDS-5 score ≥ 2 points was defined as depression (Hoyl et al., 1999).

2.5. Statistical analysis

Characteristics of the participants with and without missing data were compared using the Mann-Whitney U test or chi-square test. The Shapiro-Wilk test was used to analyze normality of distribution for usual walking speed.

In the present study, the participants with missing data were excluded from the main analysis. The Mann-Whitney U test or chi-square test was used to compare each variable between those with and without slow walking speed. Then, we performed logistic regression analysis with slow walking speed as the dependent variable, and variables that were significantly related to slow walking speed in the univariate analysis were independent variables. Additionally, we conducted a sensitivity analysis which included all participants (those with and without missing data). Missing values were imputed using the median for continuous variables and the most frequent category for categorical variables from the available data.

Furthermore, if MVPA or step counts was independently associated with slow walking speed, receiver operating characteristic (ROC) curve analysis was conducted to identify the possible cut-off value that could

predict slow walking speed. The ROC curve was constructed by plotting sensitivity against 1-specificity, and cut-off value was selected by optimizing the sensitivity-specificity relationship. All statistical analyses were performed using the SPSS version 23.0 software package (SPSS Inc., Chicago, IL, USA), and $p < 0.05$ was considered significant.

3. Results

The mean age of the study participants was 79.9±3.6 y. Forty-two participants had missing data. The prevalence of slow walking speed was 14.9% (n = 52). Table 1 shows the comparison of characteristics between those with and without missing data. The participants with missing data had less points from the MMSE, slower ΔTMT, and slower usual walking speed compared to those without missing data. Additionally, the participants with missing data had higher prevalence of depression and slow walking speed. The results from the Shapiro-Wilk test showed that usual walking speed was normally distributed (Figure 1).

Table 2 shows the comparison of characteristics between those with

and without slow walking speed. Participants with slow walking speed were older and had a weaker grip strength, longer ΔTMT, higher prevalence of depression, and less MVPA and step counts.

Table 3 shows the results from the logistic regression analysis. In the univariate analysis, both MVPA and step counts were significantly and inversely associated with slow walking speed. In the logistic regression analysis, duration of MVPA was significantly and inversely associated with slow walking speed (adjusted odds ratio [OR] = 0.94 per 1 min/d increment, 95% confidence interval [CI] = 0.73-0.99; $p = 0.031$). In contrast, step counts was not significantly associated with slow walking speed in the multivariate analysis (adjusted OR = 0.94 per 1000 steps/d increment, 95% CI = 0.73-1.21; $p = 0.695$).

Table 4 shows the results from the sensitivity analysis including all participants. Both MVPA and step counts were significantly and inversely associated with slow walking speed in the univariate analysis. On the other hand, in the multivariate analysis, duration of MVPA was significantly and inversely associated with slow walking speed (adjusted OR = 0.94 per 1

min/d increment, 95% CI = 0.89-0.99; p = 0.049), whereas step counts was not significantly associated with slow walking speed (adjusted OR = 0.93 per 1000 steps/d increment, 95% CI = 0.74-1.18; p = 0.570).

The ROC curve analysis, using slow walking speed as an outcome, identified a cut-off value of 8.7 min/d of MVPA as the optimal predictive value, with a sensitivity of 75.6% and a specificity of 72.7%; the AUC was 0.779 (95% CI = 0.695-0.895; p < 0.001) (Figure 2).

4. Discussion

The main finding from this study was that duration of habitual MVPA was negatively associated with slow walking speed, independent from step counts and other confounding factors in old-old women. Our results suggest that that MVPA may play a key role in preventing the decline in neuromuscular function related to walking speed in old-old women.

Slow walking speed predicts falls, disability, nursing home stays and mortality, independent from other frailty indicators such as muscle strength, cognitive decline and depression (Rothman, Leo-Summers, & Gill, 2008).

With increasing evidence, slow walking speed in an aged population is considered a strong prognostic parameter of mortality among elderly people (Studenski et al., 2011). In addition to aging, slow walking speed is caused by sensorimotor and psychological functional decline (Tiedemann et al., 2005). Physical inactivity is likely to be a risk factor of slow walking speed because it causes progressive loss of lean body mass and mobility limitation (Pahor et al., 2014; Shephard et al., 2013). The findings of our study are consistent with those of the previous studies and suggest that promoting duration of habitual MVPA, not just increasing step counts, may be a beneficial element of PA because of the independent relationship between MVPA and slow walking speed.

Several possible mechanisms are speculated to link MVPA and slow walking speed. The loss of skeletal muscle mass due to aging is mainly attributed to a reduction in the size of type II fast twitch muscle fiber (Porter, Vandervoort, & Lexell, 2007). According to the "size principle" (Henneman, Somjen & Carpenter, 1965), high-intensity PA can promote type II fiber activity and, in turn, contribute to functional preservation. Another possible

reason is the effect of MVPA on executive function. Executive function, which was measured as ΔTMT in the present study, is known as a predictor of mobility disability in elderly people (Vazzana et al., 2010). Increasing intensity of exercise increases cerebral blood flow (Delp et al., 2001), as well as serum brain-derived neurotrophic factor level (Ferris, Williams. & Shen, 2007). This evidence leads to a hypothesis that high-intensity PA may affect walking speed directly by activating executive function through some neuroprotective mechanisms. Furthermore, a previous intervention study demonstrated that long-term moderate to high intensity brisk walking improved peripheral nerve function in diabetic patients without signs and symptoms of diabetic peripheral neuropathy (Balducci et al., 2006). Additionally, positive effects of moderate intensity endurance exercise on the progression of diabetic peripheral neuropathy have also been reported (Dixit, Maiya, & Shastry, 2014). This evidence suggests that MVPA affects physical health via peripheral nerve function improvement, which is associated with muscle function and walking ability (Resnick et al., 2000; Ward et al., 2014). The causal effects of promoting MVPA should be considered as a primary

strategy to maintain better health status in elderly people.

The World Health Organization recommends 150 min of moderate intensity PA or 75 min of vigorous intensity PA per wk for people aged 65 or over (World Health Organization, 2010). With regard to mobility function, a previous study in elderly women reported that an optimal cut-off value of MVPA to predict mobility limitation was 107.4 min/wk (approximately 15.3 min/d); mobility limitation was defined as self-reported difficulty in walking a quarter mile or climbing 10 steps without resting (Osuka et al., 2014). However, there is a lack of evidence to build robust recommendations for promoting MVPA in old-old people. In the present study in old-old women, duration of habitual MVPA was negatively associated with slow walking speed, independent from step counts and other potential confounding factors. Moreover, considering the result from the ROC curve analysis, engagement in MVPA longer than 8.7 min/d may be key to maintaining one's walking speed rather than merely increasing the amount of walking in old-old women.

Both grip strength and depression have been reported to be associated

with walking speed in elderly people (Alley et al., 2014; Hicks et al., 2012; Sallinen et al., 2010; Stevens et al., 2012). In this study, we also observed the significant and independent association between slow walking speed and both of these measures. Since muscle weakness and depression are also major health issues in elderly people (Sonnenberg et al., 2013; Yamada et al., 2013), these conditions should be considered as important confounding factors when the association of walking speed with PA is examined in elderly people.

With regard to methods used to assess walking speed, there is little consensus about testing protocols that include pace and timed walking distance. In the present study, we measured 10 m of usual walking speed using a 14-m walkway with 2 m for acceleration and 2 m for deceleration. A previous study in elderly people demonstrated a strong reliability of both the 10-m and 4-m walk tests, and a large agreement between the two methods (Peters et al., 2013). However, it was also reported that the difference between walking speed times measured using a stopwatch versus using an automatic timer was slightly longer in the 4-m walk test than in the 10-m

walk test, especially in individuals with faster walking speeds (Peters et al., 2013). Since walking speed was assessed using a stopwatch in healthy individuals in the present study, it was reasonable to use a 10-m walkway. On the other hand, previous studies reported that walking speed was slightly faster in a 10-m walkway than in a shorter walkway (Ng et al., 2013; Peters et al., 2013). Therefore, our data likely showed faster mean walking speed compared to a previous study using a shorter walkway (Yoshimura et al., 2011).

There are several study limitations that should be discussed. First, the subjects in this study voluntarily participated in the parent cohort study, potentially causing selection bias. However, the prevalence of slow walking speed in our study (14.9%) is slightly lower than that of a Japanese epidemiological study with individuals aged 65 years old or over (16.8%) (Shimada, Makizako, et al., 2013). Second, although the participants were blinded their measured PA on accelerometer and were instructed to continue normal activity of daily living during the measurement, wearing accelerometer had a possibility to stimulate PA of the participants. Third,

there may be other unknown confounders including sociological factors. Finally, the present study could not examine cause-effect relationships since it was a cross-sectional study. Nevertheless, our study still has clinical significance in terms of showing that promoting MVPA may be an effective strategy for preventing slow walking speed.

5. Conclusion

In conclusion, the findings from the present study suggest that promoting MVPA may be helpful in maintaining walking speed. Our ongoing prospective cohort study to explore the risk factors for slow walking speed will verify the predictive validity of MVPA.

Conflicts of interest

The authors declare no conflict of interest.

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Tables

Table 1. Comparison of characteristics between those with and without missing data

	Total participants		Complete data		Incomplete data		*p*
	N		n		n		
Age (years)	350	79.9 ± 3.6	308	79.9 ± 3.6	42	80.3 ± 3.7	0.464
BMI (kg/m^2)	350	21.9 ± 3.3	308	22.0 ± 3.3	42	21.7 ± 3.8	0.636
Grip strength (kg)	350	20.1 ± 3.7	308	20.3 ± 3.7	42	19.0 ± 3.8	0.088
Pain (%)	350	60.3	308	59.7	42	64.3	0.572
MMSE (points)	350	27.8 ± 2.3	308	28.0 ± 2.1	42	26.4 ± 3.2	<0.001
ΔTMT (sec)	349	105.3 ± 78.3	308	101.2 ± 75.7	41	136.3 ± 91.0	0.009
Depression (%)	346	16.5	308	14.9	38	28.9	0.028
MVPA (min/d)	313	16.7 ± 15.6	308	17.1 ± 16.6	5	19.0 ± 10.2	0.389
Step counts (steps/d)	313	6504 ± 2975	308	6523 ± 2990	5	5374 ± 1490	0.373
Usual waking speed (m/sec)	350	1.23 ± 0.23	308	1.24 ± 0.22	42	1.13 ± 0.24	0.002
Slow walking speed (%)	350	14.9	308	13.3	42	26.2	0.028

Continuous variables were shown by mean±standard deviation

BMI, body mass index; MMSE, Mini Mental State Examination; ΔTMT, ΔTrail Making Test; MVPA, moderate to vigorous physical activity

p : Complete data vs Incomplete data by Mann Whitney U test or chi-square test

Table 2. Comparison of characteristics between those with and without slow walking speed

	No slow walking speed (n=267)	Slow walking speed (n=41)	*p*
Age (years)	79.5 ± 3.4	80.3 ± 3.7	<0.001
BMI (kg/m^2)	22.0 ± 3.3	21.7 ± 3.8	0.683
Grip strength (kg)	20.7 ± 3.5	17.7 ± 3.8	<0.001
Pain (%)	57.7	73.2	0.060
MMSE (points)	28.1 ± 2.0	27.4 ± 2.5	0.082
ΔTMT (sec)	95.3 ± 70.2	139.6 ± 97.4	<0.001
Depression (%)	12.7	29.3	0.006
MVPA (min/d)	18.5 ± 16.8	7.6 ± 10.9	<0.001
Step counts (steps/d)	6800 ± 2948	4718 ± 2639	<0.001
Usual waking speed (m/sec)	1.30 ± 0.18	0.88 ± 0.12	<0.001

Continuous variables were shown by mean±standard deviation

BMI, body mass index; MMSE, Mini Mental State Examination; ΔTMT, ΔTrail Making Test; MVPA, moderate to vigorous physical activity

p : No slow walking speed vs slow waking speed by Mann Whitney U test or chi-square test

Table 3. Results of logistic regression analysis in those with complete data

	Unadjusted OR	[95%CI]	*p*	Adjusted OR[a]	[95%CI]	*p*
Age, per 1 y increment	1.20	[1.10-1.31]	<0.001	1.08	[0.98-1.20]	0.131
BMI, per 1kg/m^2 increment	1.00	[0.97-1.11]	0.954		-	
Grip strength, per 1kg increment	0.77	[0.69-0.86]	<0.001	0.82	[0.73-0.93]	0.001
Pain	2.00	[0.96-4.16]	0.063		-	
MMSE, per 1 point increment	0.86	[0.74-0.99]	0.042	0.94	[0.77-1.14]	0.504
ΔTMT, per 1 sec increment	1.06	[1.02-1.10]	0.001	1.00	[1.00-1.01]	0.127
Depression	2.84	[1.31-6.08]	0.007	2.73	[1.12-6.68]	0.028
MVPA, per 1 min/d increment	0.90	[0.86-0.95]	<0.001	0.94	[0.73-0.99]	0.031
Step counts, per 1000 steps/d increment	0.71	[0.61-0.83]	<0.001	0.94	[0.73-1.21]	0.695

Dependent variable: slow walking speed

[a]Independent variables: age, grip strength, MMSE, ΔTMT, MVPA, step counts

OR, odds ratio; CI, interval confidence; BMI, body mass index; MMSE, Mini Mental State Examination; TMT, ΔTrail Making Test; MVPA, moderate to vigorous physical activity

Table 4. Results of logistic regression analysis including all participants

	Unadjusted OR	[95%CI]	*p*	Adjusted OR[a]	[95%CI]	
Age, per 1 y increment	1.22	[1.13-1.33]	<0.001	1.12	[1.02-1.23]	0.018
BMI, per 1kg/m^2 increment	1.00	[0.92-1.09]	0.972		-	
Grip strength, per 1kg increment	0.78	[0.71-0.86]	<0.001	0.74	[0.73-0.90]	<0.001
Pain	1.58	[0.84-2.98]	0.155		-	
MMSE, per 1 point increment	0.86	[0.76-0.96]	0.008	0.97	[0.83-1.13]	0.696
ΔTMT, per 1 sec increment	1.01	[1.00-1.01]	0.001	1.00	[0.99-1.01]	0.115
Depression	2.79	[1.42-5.47]	0.003	2.27	[1.05-4.89]	0.036
MVPA, per 1 min/d increment	0.92	[0.88-0.96]	<0.001	0.94	[0.89-0.99]	0.049
Step counts, per 1000 steps/d increment	0.73	[0.64-0.85]	<0.001	0.93	[0.74-1.18]	0.570

Dependent variable: slow walking speed

[a]Independent variables: age, grip strength, MMSE, ΔTMT, MVPA, step counts

OR, odds ratio; CI, interval confidence; BMI, body mass index; MMSE, Mini Mental State Examination; TMT, ΔTrail Making Test; MVPA, moderate to vigorous physical activity

Figure legends

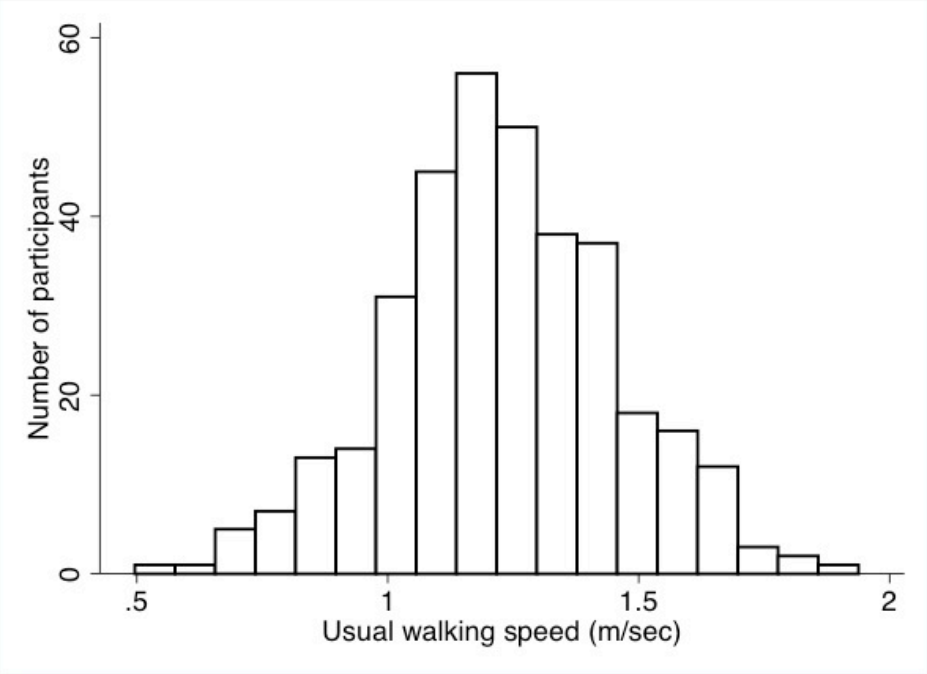
Figure 1. Distribution of usual walking speed

Mean usual walking speed was 1.23±0.23 m/sec.

The Shapiro-Wilk test showed a normal distribution ($p = 0.725$).

Figure 2. Receiver operating characteristic curve for predicting slow walking speed using moderate to vigorous physical activity

AUC, area under the curve; CI, confidence interval



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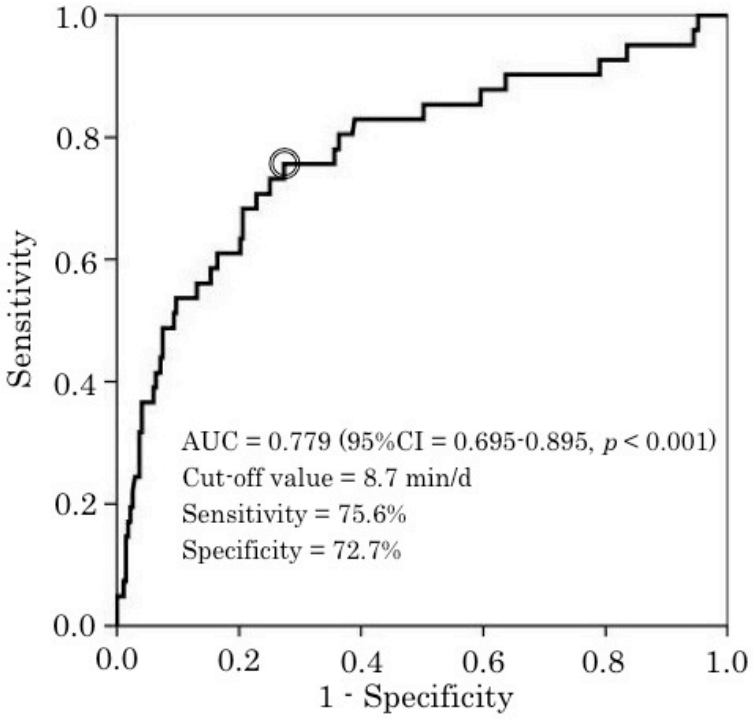

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