Cognitive function

Cognitive function was evaluated by comprehensive neuropsychological assessment and conducted by a well-trained speech therapist. Processing speed was assessed using a tablet version of the Symbol Digit Substitution Task (SDST) [30], based on the Symbol Digit Modalities Test [31]. The score is the number of correct answers chosen within 90 s. Executive function was evaluated using a tablet version of the Trail Making Test Part B (TMT-B, 15 stimuli) [30]. We recorded the amount of time it took to complete each task, and results were excluded from analysis if this time was greater than 90 seconds. Working memory was assessed using the digit span backward test, a subset of the Wechsler Adult Intelligence Scale III [32]. Verbal memory was assessed using the Rey Auditory Verbal Learning Test (RAVLT) [33]. Visual memory was examined using the visual reproduction subtest of the Wechsler Memory Scale-Revised (WMS-R) [34]. Better performance is represented by lower values in the TMT-B and higher values in the other tests.

Other covariates

Age, sex, body mass index (weight/height^2), and educational history were recorded as demographic data. Medical conditions and current medications were recorded. Apolipoprotein E (APOE) genotype was assessed using genomic DNA extracted from peripheral blood leukocytes or autopsy tissues using a standard method (SRL, Inc., Tokyo, Japan). The genotyped data were strictly controlled under condition of anonymity and blinded from the clinical information. Carrying ε4 is thought to be a strong factor related to deterioration of cognitive function in MCI participants [35]. To assess functional capacity, we used the Tokyo Metropolitan Institute of Gerontology Index of Competence [36] and activity level was measured using a life-space assessment [37].

Statistical analysis

We compared participant characteristics between MCI subtypes (aMCI and naMCI) using an unpaired *t*-test for continuous variables or a chi-square test for categorical variables. Before examining the association between cognitive functions and gait variables, we first compared cognitive functions and gait variables between aMCI and naMCI groups. To compare cognitive function, we used a general linear model adjusted for age, which is thought to be a strong covariate, and participant characteristics that differed significantly between MCI subtypes. For gait variables, we used a repeated-measures analysis of variance (ANOVA) (adjusted for the same variables as above) to test for the main effects of MCI subtype (aMCI or naMCI) and walking condition (NW or DTW). To examine whether cognitive functions were independently associated with gait speed, we used a multivariable regression analysis adjusted for age, sex, body mass index, education, medication, life space, functional capacity, and APOE status as potential covariates. This adjusted model is conducted against gait speed under NW and DTW (model 1). Additionally, to clarify the association between cognitive function and gait speed under DTW, model 2 adjusted variables using model 1 added to gait speed in NW was conducted (model 2). All analyses were performed using commercially available software (JMP 9.0 J for Windows; SAS Institute Japan, Tokyo, Japan). Statistical significance was set at $p < .05$.

Results

The 389 participants (52% women, mean age: 71.6 years) were classified as either aMCI (n = 191) or naMCI (n = 198). Table 1 summarizes the demographic data including educational history, current medication, functional capacity, life space, and status of APOE. The proportion of women was significantly different between MCI groups (aMCI: n = 79, 41%; naMCI: n = 124, 63%; $p < .001$), while other demographic variables were not. Therefore, when comparing cognitive functions between MCI groups, we adjusted for age and sex. RAVLT scores were lower in aMCI participants, while SDST scores were lower in

Table 1 Subject characteristics

Variables	*M* ± *SD*
Age (years)	71.6 ± 4.9
Sex (women subjects (%))	203 (52)
Body mass index (kg/m^2)	23.4 ± 2.9
Educational history (years)	11.0 ± 2.4
TMIG (score)	12.4 ± 1.1
Life-space assessment (score)	90.2 ± 15.7
Current medications (numbers)	2.2 ± 2.0
Type of MCI (amnestic MCI (%))	191 (49)
Status of apolipoprotein E (ε4 carrier (%))	76 (20)
Cognitive tests	
MMSE (score)	26.7 ± 1.9
SDST (score)	38.9 ± 7.4
TMT-B (s)	43.5 ± 16.7
Digit span backward (score)	5.1 ± 1.6
RAVLT-delay (score)	7.3 ± 3.4
Visual reproduction (score)	21.9 ± 8.8
Normal walking	
Gait speed (m/s)	1.36 ± 0.22
Dual-task walking	
Gait speed (m/s)	1.23 ± 0.32

Note: TMIG: Tokyo Metropolitan Institute of Gerontology Index of Competence. MCI: mild cognitive impairment. SDST: Symbol Digit Substitution Task. TMT-B: Trail Making Test Part B. RAVLT: Rey Auditory Verbal Learning Test
Values are mean ± SD or numbers (proportion).

naMCI participants (RAVLT: $p < .001$, SDST: $p = .002$). No significant differences between groups were found for the other cognitive functions. A repeated-measures ANOVA adjusted for age and sex showed that gait speed was affected by walking condition (NW vs. DTW: $p = .042$), but not by MCI group (naMCI vs. aMCI: $p = .301$).

Simple correlation analysis showed a significant relationship between normal gait speed and all cognitive functions in all MCI participants (SDST: $r = .406$, $p < .0001$; TMT-B: $r = -.375$, $p < .0001$; digit span: $r = .122$, $p = .0166$; RAVLT: $r = .209$, $p < .0001$; visual reproduction: $r = 0.306$, $p < .0001$). DTW was also significantly associated with cognitive functions in all MCI participants (SDST: $r = .395$, $p < .0001$; TMT-B: $r = -.373$, $p < .0001$; digit span: $r = .307$, $p < .0001$; RAVLT: $r = .238$, $p < .0001$; visual reproduction: r = .325, $p < .0001$). Results from cognitive function tests are plotted against gait speed in Figure 1 (NW) and Figure 2 (DTW). A multivariate regression analysis adjusted for potential covariates was conducted and the results for gait variables during NW are summarized in Table 2. During NW, gait speed was associated with SDST scores in both MCI groups (aMCI: $p = .003$; naMCI: $p = .009$), with visual reproduction scores in aMCI participants ($p = .037$), and with TMT-B scores in naMCI participants ($p = .025$). Digit span and RAVLT were not significantly associated with gait speed during NW. Associations with gait speed during DTW are summarized in Table 3. Cognitive functions other than RAVLT correlated with gait speed in DTW even adjusted for normal gait speed in aMCI participants (all tests, $p < .05$), while only digit span did so in naMCI participants ($p < .001$).

Discussion

The results of this study indicate positive associations between cognitive functions and gait speed in MCI participants. The independent associations were revealed by a multivariate analysis adjusting for several potential confounding factors including the status of APOE. Processing speed and executive function correlated with gait speed during NW and DTW. Working memory was significantly associated with gait speed during DTW in both subtypes of MCI participants. Visual memory was also associated with gait speed in NW and DTW particularly in aMCI participants.

Our study showed that cognitive function in MCI participants is correlated with gait speed, and that this association differs depending on walking conditions (normal or dual-task). Indeed, some prospective studies have touched on this inter-relationship. Gait speed during NW has been shown to be related to cognitive decline [12], MCI [7], and risk of dementia [8], while impaired cognitive functions have been shown to be related to a decline in normal gait speed [9,11,13]. The majority of studies investigating this relationship have focused on normal gait speed and processing speed [12] or executive function [9,13], and have confirmed the relationship

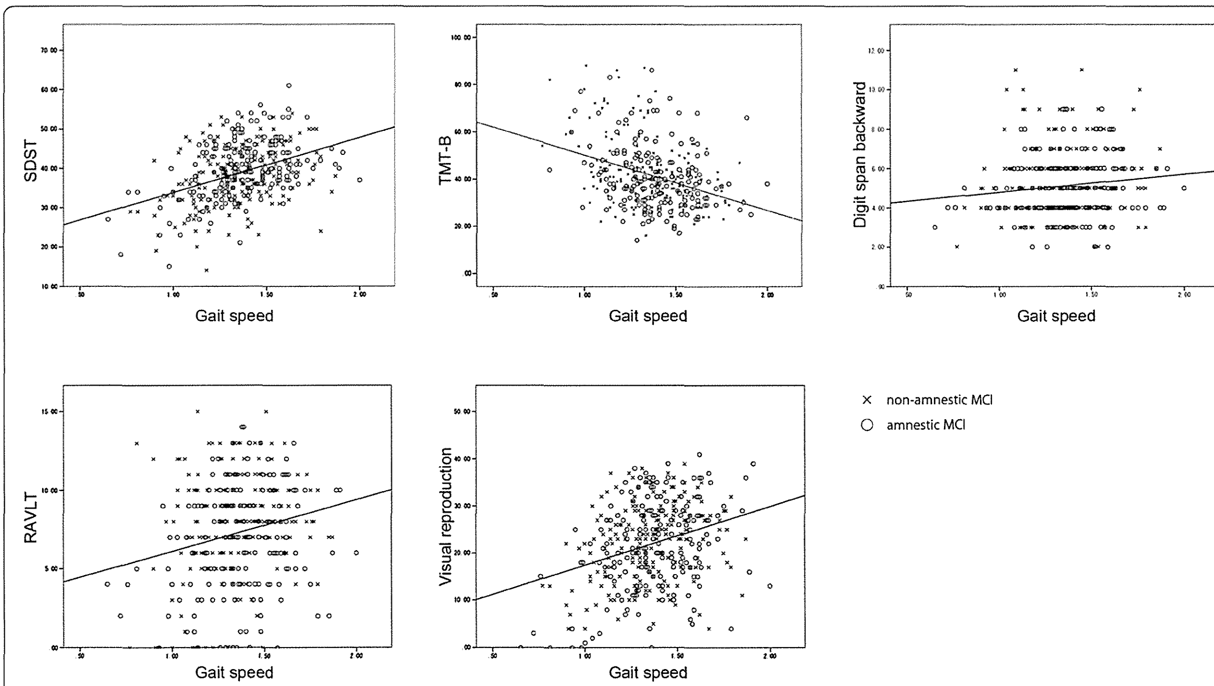

Figure 1 Cognitive measurements and gait speed during normal walking. Scatter plots showing scores of cognitive measurements and gait speed (m/s) during normal walking, grouped by MCI subtype. Lines indicate the resulting regression line for all participants.

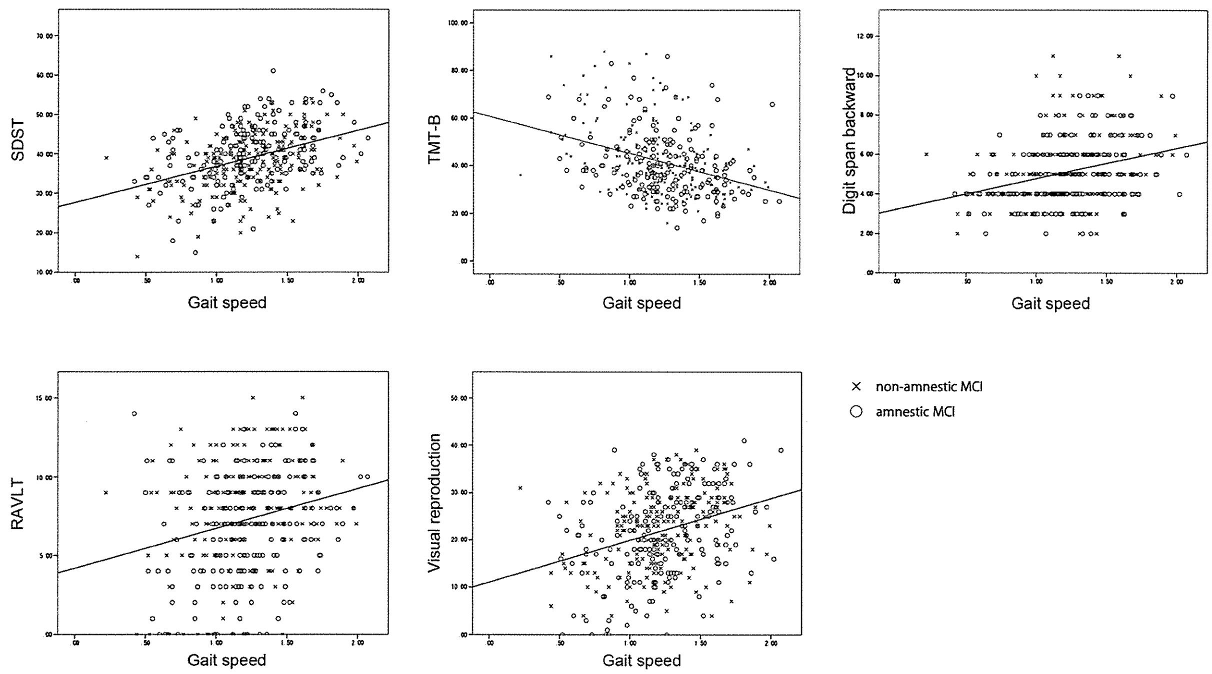

Figure 2 Cognitive measurements and gait speed during dual-task walking. Scatter plots showing scores of cognitive measurements and gait speed (m/s) during dual-task walking grouped by MCI subtype. Lines indicate the resulting regression line for all participants.

in older adults. Consistent with our results in MCI participants, McGough *et al.* have reported that physical performance is associated with executive function after adjusting for age, sex, and age-related factors in sedentary older adults with aMCI [38]. Here, we show that in addition to processing speed and executive function, gait speed during DTW is also associated with working memory in MCI participants, even after adjusting for normal gait speed. The effect of DTW on gait variables [24,25] and the requirement for executive function in older adults have been reported [21,22], and cognitive impairment (e.g., MCI) has been shown to have an impact on DTW performance. Montero-Odasso *et al.* [26] suggested that gait speed in MCI participants is related to working memory ability, and that the relationship is exaggerated during DTW. Our results partially agree with their study in that working memory was correlated with gait variables during DTW but not NW. Executive function is thought to be dominant in prefrontal lobe function. Processing speed has been reported to correspond to prefrontal lobe function, a region also thought to have a role in gait control [39]. Working memory systems are believed to be dominated and require similar neural resources in prefrontal cortex [40], although the resources for these functions are not fully identical. Our study supports the idea that prefrontal lobe function is required for gait in MCI participants.

Table 2 Multivariable regression results between cognitive function and gait speed during normal walking

Cognitive measures	Cognitive domain	Coefficients (SE)		
		aMCI	naMCI	Total
		(n = 191)	(n = 198)	(n = 389)
SDST	Processing speed	.216 (0.002)†	.202 (0.002)†	.209 (0.002)‡
TMT-B	Executive function	-.095 (0.001)	-.287 (0.001)‡	-.180 (0.001)‡
Digit span backward	Working memory	.013 (0.009)	.006 (0.009)	.006 (0.006)
RAVLT-delay	Verbal memory	.087 (0.004)	.025 (0.005)	.036 (0.003)
Visual reproduction	Visual memory	.142 (0.002)*	.066 (0.002)	.111 (0.012)*

Note: aMCI: amnestic mild cognitive impairment. naMCI: non-amnestic mild cognitive impairment. SDST: Symbol Digit Substitution Task. TMT-B: Trail Making Test Part B. RAVLT: Rey Auditory Verbal Learning Test.
Multivariable regression was adjusted for age, sex, body mass index, education, medication use, life space, functional capacity, and apolipoprotein E status.
**p* < .05. †*p* < .01. ‡*p* < .001.

Table 3 Multivariable regression results between cognitive function and gait speed during dual-task walking

Cognitive measures	Cognitive domain	Coefficients (SE)					
		Model 1			Model 2		
		aMCI (n = 191)	naMCI (n = 198)	Total (n = 389)	aMCI (n = 191)	naMCI (n = 198)	Total (n = 389)
SDST	Processing speed	.349 (0.004)‡	.214 (0.003)†	.269 (0.002)‡	.195 (0.003)†	.093 (0.003)	.134 (0.002)†
TMT-B	Executive function	-.203 (0.002)*	-.265 (0.002)†	-.237 (0.001)‡	-.148 (0.001)*	-.092 (0.001)	-.121 (0.001)†
Digit span backward	Working memory	.234 (0.015)†	.214 (0.013)†	.227 (0.010)‡	.226 (0.012)‡	.210 (0.009) ‡	.223 (0.007)‡
RAVLT-delay	Verbal memory	.174 (0.007)*	.047 (0.007)	.101 (0.005)	.120 (0.006)	.032 (0.005)	.079 (0.004)
Visual reproduction	Visual memory	.252 (0.003)‡	.109 (0.003)	.196 (0.002)‡	.166 (0.002)†	.068 (0.002)	.128 (0.002)†

Note: aMCI: amnestic mild cognitive impairment. naMCI: non-amnestic mild cognitive impairment. SDST: Symbol Digit Substitution Task. TMT B: Trail Making Test Part B. RAVLT: Rey Auditory Verbal Learning Test.
Model 1: Multivariable regression was adjusted for age, sex, body mass index, education, medication use, life space, functional capacity, and apolipoprotein E status. Model 2: adjusted for variables in model 1 and gait speed in normal walking.
$^*p < .05$. $^†p < .01$. $^‡p < .001$.

The associations between cognitive function and gait speed differed depending on MCI subtype. To our knowledge, this is the first report showing that memory function requiring free recall is correlated with gait variables specifically in aMCI participants. Although a consensus regarding the relationship between memory function and gait ability has not been reached in studies of healthy older adults, our results are in line with prospective studies of healthy older adults [9,11]. Memory function in MCI, particularly aMCI, is a clinical signature of developing AD [2]. However, whether or not memory function relates to gait variables remains an open debate even when including studies using neuroimaging [41,42]. Unlike executive function, investigations focusing on the connection between memory and gait ability are few, and those that do have used variable measures of memory (e.g., verbal memory or visual memory). We examined verbal memory (RAVLT) and visual memory (visual reproduction subtest of the WMS-R) separately. Gait speed during both NW and DTW conditions correlated with visual memory functions in aMCI participants, while verbal memory function never correlated with gait speed. This result may reflect the fact that visual memory is required for visuospatial processing in addition to simple memory functions. In fact, cortical thickness [43] and gray matter [41] in visual processing regions are correlated with gait variables during NW. Further study is required to clarify the relationship between memory function and gait performance.

Our study had several strengths and limitations. We used a large cohort with a sufficient sample size. Additionally, our analysis included adjustments for several potential covariates, such as the status of APOE, that affect not only pathogenesis (e.g., Aβ aggregation or neural toxicity) [44] but cognitive decline [35]. However, some limitations must be noted. Because a cross-sectional design was used, the causal relationship between cognitive function and gait is still unclear in people with MCI. Further prospective studies are required to address this issue. Additionally, the type and/or difficulty of the cognitive task used for DTW could have affected the results. While the mental tracking task we adopted (counting backwards) is widely used, the effects of dual tasking on gait may depend on the cognitive task [24]. Hence, DTW using other types of cognitive tasks (e.g., verbal fluency) should be investigated. Finally, neuroimaging methods have recently been used to clarify the cortical control of gait. Further evidence using imaging techniques should be gathered to clarify the association between cognitive function and gait ability under varied conditions.

Conclusion

Successful DTW for those with MCI may require adequate cognitive function, processing speed, executive function, working memory and visual memory. The association between cognitive functions and gait variables partially depends on the MCI subtype. Gait speed in both NW and DTW are associated with memory performance particularly in MCI participants whose memory performance has declined (aMCI) compared with those with relatively intact memory functions (naMCI). Further studies are needed to clarify the effects of cognitive function on gait in MCI participants.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

TD substantially contributed to the conception of the methods used, participant recruitment, analysis and writing the manuscript. HS and HM made substantial contributions to conception and design, participant recruitment, and writing the manuscript. KT and KU were involved in the acquisition, analysis and interpretation of data. YA contributed to the acquisition of data. TS made substantial contributions to the conception and design and writing the manuscript. All authors read and approved the final manuscript.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Association of knee-extension strength with instrumental activities of daily living in community-dwelling older adults

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Aim: The purpose of the present study was to investigate the relationship between knee-extension (KE) strength and instrumental activities of daily living (IADL), and to examine the risk of IADL disability in relation to KE strength in community-dwelling older adults.

Methods: The participants were 1235 community-dwelling older adults (261 men and 974 women) in Tokyo who underwent a comprehensive health survey in 2009. The health survey included measurement of KE strength and a questionnaire on the Tokyo Metropolitan Institute of Gerontology (TMIG)-IADL. Pearson product-moment correlation coefficients and partial correlation coefficients were calculated separately for each sex for four parameters representing quadriceps muscle strength and TMIG-IADL. Pearson's χ^2-test of independence and the Cochran–Armitage test of trend were also carried out to determine the relationship between KE strength and IADL disability.

Results: In women, all correlations between the quadriceps muscle strength parameters and the TMIG-IADL score were statistically significant ($P < 0.0005$). The significance persisted remained even after factors regarding cognition or depression were taken into consideration. Furthermore, the percentage of female participants with IADL disability was dependent on KE strength; there was an inverse trend between KE strength and the percentage of people with IADL disability. In men, no significant relationship was found between KE strength and IADL.

Conclusions: KE strength and IADL correlated positively, and the percentage of people with IADL disability decreased with increasing KE strength in women. **Geriatr Gerontol Int 2014; 14: 674–680.**

Keywords: activities of daily living, aged, knee, muscle strength, quadriceps muscle.

Introduction

The instrumental activities of daily living (IADL) are the activities often carried out by a person who is living independently in a community setting during the course of a normal day, such as managing money, shopping, telephone use, travel in the community, housekeeping, preparing meals and taking medications correctly.[1] Declines in the ability to carry out these activities might result in the need for long-term care. Therefore, the unprecedented rate of aging seen in Japan today necessitates the identification of measures to prevent the decline of IADL in the elderly.

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Several studies have reported that hand muscle strength is related to IADL. For example, a meta-analysis of community-dwelling older participants by Judge *et al.* showed that handgrip strength was negatively related to the total number of IADL requiring assistance from others.[2] Sallinen *et al.* reported that handgrip strength below 37 kg for men and 21 kg for women increased the likelihood of mobility limitations, which are directly related to IADL disability.[3] A 3-year follow-up study by Ishizaki *et al.* also pointed out that weak handgrip strength was a significant predictor of functional decline in IADL performance.[4]

As most IADL involve walking, leg muscle strength might also greatly affect the performance of IADL. However, an association between lower-limb muscle strength and IADL cannot be assumed, as one could, for example, substitute a wheelchair for walking, to carry out each activity included in the IADL.

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A multivariate analysis carried out by Uchida *et al.* showed that poor performance on the knee-raising test correlated strongly with decreased IADL performance.[5] A study by Azegami *et al.* involving 47 elderly people investigated the effect of lower-extremity muscle strength on IADL status in two ways: knee-extension (KE) in a single-joint task and total leg extension (TLE) in a multijoint task.[6] The authors found that there was a significant difference in TLE strength between participants with total and only partial IADL independence, whereas no such difference was found for KE strength in a single joint.

In many studies, the strength of lower-limb muscles has often been represented by KE strength,[7–9] as this measurement of the isometric strength of the quadriceps muscles in the sitting position is well established. The purpose of the present study was to examine the relationship between KE strength and IADL performance in a local elderly population.

Methods

Participants

The data were taken from a health survey carried out by Tokyo Metropolitan Institute of Gerontology (TMIG) for community-dwelling older adults in the Itabashi ward of Tokyo in 2009. The participants in the 2009 survey consisted of 1235 people (261 men and 974 women). This group of participants included two cohorts (2002 and 2006 cohorts). All the men (n = 261) and 405 of the women participated in a health survey carried out in 2002 (2002 cohort). Follow-up surveys were carried out for this cohort four times, including the survey in 2009. The remaining 569 women first participated in the health survey carried out in 2006 (2006 cohort). Follow-up surveys for this cohort were carried out once in 2007 and once in 2009.

A total of 15 men and 47 women whose IADL or KE data were not available were excluded from the study; the present study analyzed data from 246 men (age range, 77–91 years) and 927 women (age range, 72–91 years) (Table 1). The TMIG ethics committee approved this study. All participants gave their written consent.

Measurement of KE strength

KE strength was measured isometrically using a hand-held dynamometer (μTas F-1; ANIMA, Tokyo, Japan). The participants were seated on a custom-made chair with their feet hanging. Participants practiced isometric knee extension by pushing against the tester's hand. The dynamometer was then placed 5 cm above the top of the lateral malleolus, and the chair was adjusted to ensure that the participant's knees were flexed at 90°. Voluntary maximal isometric knee extension effort was exerted twice on the dominant leg. Participants received consistent verbal encouragement as reinforcement. The greater value of two trials was used for analysis. The distance from the lateral knee joint space to the lateral point of the height of the dynamometer pad (F-L distance in Table 1) was measured to convert KE strength into KE torque. Those who were diagnosed with a serious medical problem (e.g. systolic blood pressure over 180 mmHg, diastolic blood pressure over 110 mmHg, or heart attack or cerebral stroke in the past 6 months) were excluded from the test for safety reasons.

Evaluation of IADL performance

IADL performance was assessed using a five-item list from the TMIG Index of Competence for instrumental self-maintenance,[10] which was developed for elderly Japanese participants and has been widely used in Japanese communities. The list assessed the following five activities: (i) using public transportation; (ii) shopping for daily necessities; (iii) preparing meals; (iv) paying bills; and (v) handling a bank account (Table 2). The response to each item was either "yes" (able to accomplish, 1 point) or "no" (unable to accomplish, 0 points). The IADL score (TMIG-IADL hereafter) was calculated as the total number of points.

Evaluation of other parameters potentially related to KE strength and IADL performance

To identify parameters that were related to both KE strength and IADL, which might result in a spurious correlation between the two, data on several other parameters were collected. Bodyweight was measured as a part of the body fat measurement. Cognitive function was evaluated using the Mini-Mental State Examination (MMSE), for which a higher score indicates better cognitive function.[11] Depression was assessed using the Mini-International Neuropsychiatric Interview (MINI);[12] those who gave a negative response to both of the first two questions were categorized as normal, and those who gave a positive response to either of these questions were categorized as depressed. A history of disease (hypertension, stroke, heart disease, diabetes mellitus, hyperlipidemia, osteoporosis, anemia, chronic kidney deficiency, asthma, chronic occlusive pulmonary disease [COPD], pneumonia, osteoarthritis of the hip, gonarthritis, or fracture occurring above the age of 60 years) and the use of drugs was assessed using yes/no questions. Family status was examined using one multiple-choice question, and the participants were categorized as "living alone" or "living with someone".

Data analysis

For quantitative variables, means and standard deviations were calculated. For qualitative variables assessed

Table 1 Basic participant characteristics

			Male (n = 246) Mean ± SD	Female (n = 927) Mean ± SD	Difference between sexes
Mean ± SD		Age (years)	82.2 ± 3.5	79.5 ± 4.2	‡
		Height (cm)	160.8 ± 5.8	147.8 ± 5.6	‡
		Weight (kg)	58.4 ± 8.6	48.8 ± 7.6	‡
		F-L Distance (cm)	27.1 ± 2.3	25.0 ± 2.0	‡
		KES (N)	292.4 ± 82.8	209.1 ± 58.5	‡
		TMIG-IADL	4.9 ± 0.4	4.9 ± 0.5	N.S.
		MMSE	27.7 ± 2.3	27.6 ± 2.3	N.S.
Percent Positive	History	Depression	4.9%	3.9%	N.S.
		Hypertension	58.1%	55.8%	N.S.
		Stroke	10.2%	6.6%	N.S.
		Heart disease	23.6%	22.0%	N.S.
		Diabetes mellitus	11.8%	8.5%	N.S.
		Hyperlipidemia	18.7%	36.1%	‡
		Osteoporosis	6.1%	34.1%	‡
		Anemia	2.8%	3.8%	N.S.
		CKD	2.0%	1.1%	N.S.
		Asthma	4.1%	3.2%	N.S.
		COPD	4.5%	1.5%	‡
		Pneumonia	11.0%	6.9%	†
		Osteoarthritis of hip	2.4%	4.0%	N.S.
		Gonarthritis	15.4%	28.0%	‡
		Fracture after 60 years	13.0%	23.5%	‡
	Drug use	Anti-inflammatory	6.5%	9.5%	N.S.
		Oral steroid	1.2%	1.3%	N.S.
		Anti-osteoporosis	4.9%	30.3%	‡
		Living alone	8.1%	37.2%	‡

†$P < 0.05$, ‡$P < 0.01$. CDK, chronic kidney deficiency; COPD, chronic occlusive pulmonary disease; F-L Distance, distance from fulcrum to the point of load in knee extension task; KES, knee extension strength; SD, standard deviation.

Table 2 English translation of the questions constituting the Tokyo Metropolitan Institute of Gerontology instrumental activities of daily living

Question	Answer
1. Can you use public transportation (bus or train) by yourself?	Yes/No
2. Are you able to shop for daily necessities?	Yes/No
3. Are you able to prepare meals by yourself?	Yes/No
4. Are you able to pay bills?	Yes/No
5. Can you handle your own banking?	Yes/No

by yes/no questions, the percentage of positive responses was calculated. Differences between sexes were analyzed using the *t*-test or the χ^2-test.

We carried out a preliminary analysis to determine potentially confounding factors for the relationship between KE strength and IADL; correlations between parameters, such as body weight, MMSE, MINI, medical conditions and diseases, medication use, family status, and KE strength or TMIG-IADL, were examined individually. The statistical significance of Pearson's or Spearman's correlation coefficients was tested.

Pearson's correlation coefficients between four parameters representing quadriceps muscle strength (KE strength, KE torque, bodyweight-adjusted KE strength and bodyweight-adjusted KE torque) and TMIG-IADL scores were examined. Partial correlation coefficients using MMSE and MINI as the controlling variables were also calculated. The statistical significance of the correlations was tested.

The participants were classified according to quintiles of KE strength into five categories, and were also classified into two categories according to the presence of IADL disability; participants with a TMIG-IADL score of 1–4 were defined as having IADL disability.[13,14] The χ^2-test was carried out to determine the relationship between the percentage of participants with IADL disability and KE strength. Cochran–Armitage tests of trend were carried out to determine whether there were any trends in the prevalence of IADL disability according to the KE strength.

As the distribution of TMIG-IADL was very skewed (just 2% of men and 3% of women scored ≤3 points), the analyses were also applied to a subgroup of participants whose TMIG-IADL score was between 4 and 5. All of these analyses were carried out using PASW Statistics 18 (IBM Japan, Tokyo, Japan), except for Cochran–Armitage tests, which were carried out using an Excel program (Microsoft, Redmond, WA, USA). The level of significance was set at $P < 0.05$.

Results

Participant characteristics

The age, height, weight, F-L distance and KE strength were greater in men than in women. Hyperlipidemia, osteoporosis, gonarthritis, fracture after 60 years-of-age, use of anti-osteoporosis drugs and living alone were higher in women than in men. COPD and pneumonia were higher in men than in women. (Table 1).

Preliminary analysis of individual correlations

In men, statistically significant correlations with KE strength were observed for bodyweight ($r = 0.346$; $P < 0.0005$) and the MMSE score ($r = 0.230$; $P < 0.0005$). Statistically significant correlations with the TMIG-IADL score were observed for the MINI ($\rho = -0.134$; $P = 0.035$), stroke ($\rho = -0.145$; $P = 0.023$), heart disease ($\rho = -0.138$; $P = 0.030$) and asthma ($\rho = -0.159$; $P = 0.012$). No parameters correlated with both KE strength and the TMIG-IADL score.

In women, statistically significant correlations with KE strength were observed for bodyweight ($r = 0.343$; $P < 0.0005$), MMSE ($r = 0.160$; $P < 0.0005$), MINI ($r = -0.089$; $P = 0.007$), heart disease ($r = -0.105$; $P = 0.001$), osteoporosis ($r = -0.111$; $P = 0.001$), anemia ($r = -0.087$; $P = 0.008$) and the use of anti-osteoporosis drugs ($r = -0.084$; $P = 0.010$). Statistically significant correlations with the TMIG-IADL score were observed for the MMSE ($r = 0.302$; $P < 0.0005$), MINI ($\rho = -0.208$; $P < 0.0005$) and stroke ($\rho = -0.097$; $P = 0.003$). Thus, the MMSE and MINI correlated with both KE strength and the TMIG-IADL score. We therefore took these two parameters into consideration when we carried out the partial correlation analysis.

Correlation analysis

In men, all correlations between quadriceps muscle strength parameters and the TMIG-IADL score were statistically non-significant (Table 3). In women, all the correlations were weak (R 0.157–0.173), but statistically significant ($P < 0.0005$) (Table 3). These correlations remained significant for women even when the analysis

Table 3 Correlation coefficients between parameters related to quadriceps muscle strength and Tokyo Metropolitan Institute of Gerontology instrumental activities of daily living score

	Sex	Parameter	Correlation coefficient	Statistical significance
All participants	Male ($n = 246$)	KES	0.022	N.S.
		KET	0.030	N.S.
		WA-KES	0.066	N.S.
		WA-KET	0.072	N.S.
	Female ($n = 927$)	KES	0.173	‡
		KET	0.173	‡
		WA-KES	0.157	‡
		WA-KET	0.166	‡
Subgroup of TMIG-IADL ≥ 4	Male ($n = 241$)	KES	−0.005	N.S.
		KET	−0.001	N.S.
		WA-KES	0.010	N.S.
		WA-KET	0.012	N.S.
	Female ($n = 899$)	KES	0.109	‡
		KET	0.100	‡
		WA-KES	0.133	‡
		WA-KET	0.128	‡

†$P < 0.05$, ‡$P < 0.01$. KES, knee extension strength; KET, knee extension torque; TMIG-IADL, Tokyo Metropolitan Institute of Gerontology instrumental activities of daily living; WA-KES, weight-adjusted knee extension strength; WA-KET, weight-adjusted knee extension torque.