# Association between decreased walking speed and higher-level functional capacity in community-dwelling older women

Suguru Ando,[1,2] Masaki Iwamura,[1] Yosuke Yamato,[1] Kenji Shinbo,[1] Wataru Nanikawa[1,2]

[1]Department of Physical Therapy, Faculty of Health Science, Aino University, Osaka; [2]Graduate School of Rehabilitation Science, Osaka Metropolitan University, Japan

## Abstract

This study aimed to investigate the relationship between walking speed and higher-level functional capacity in community-dwelling older women. Data were collected from 91 healthy Japanese women aged ≥65 years (mean age, 78.7 years) in Ibaraki City, Osaka Prefecture. Participants' higher-level functional capacity was assessed using the Japan Science and Technology Agency Index of Competence (JST-IC). Participants were categorized into two groups based on walking speed (faster or slower than 1.0 m/s). Logistic regression analysis revealed that grip strength [odds ratio (OR): 0.84; 95% confidence interval (CI): 0.713-0.992], the total JST-IC score (OR: 0.82; 95% CI: 0.675-0.997), and the JST-IC subscale for use of technology (OR: 0.54, 95% CI: 0.309-0.958) were significant factors associated with decreased walking speed. The decreased walking speed observed among community-dwelling older women was related to cognitive aspects such as processing and spatial perception, as well as the use of technology. Maintaining physical and cognitive functions, particularly hand function, is crucial for preserving or improving walking speed, a barometer of health.

## Introduction

Walking speed, recognized as the "sixth vital sign", is a valid, reliable, and sensitive indicator for assessing the functional status and overall health in various populations.[1] Walking speed, especially in older adults, is a useful outcome measure and a powerful predictor of dysfunction, disease risk, and mortality.[2] Previous studies have identified specific cut-off values for walking speed in assessing and predicting dysfunction and disability in older adults. A walking speed slower than 1.0 m/s is used for diagnosing sarcopenia and frailty.[3-5] Slow walking speed and low physical activity are strong predictors of activity of daily living (ADL) disabilities in older adults.[6] Perera *et al*. reported a five- to six-fold relative risk of disabilities in individuals with walking speeds slower than 0.4 m/s based on the reference range (0.8-1.0 m/s).[7] Quach *et al.* demonstrated that a walking speed slower than 0.6 m/s and an annual speed reduction exceeding 0.15 m/s predicted an increased risk of falls.[8] Middleton *et al.* reported that older adults with self-selected walking speeds slower than 0.76 m/s or maximum walking speeds slower than 1.13 m/s should undergo fall risk assessments.[9] In cognitive function, individuals with walking speeds slower than 1.0 m/s had a two-fold increased risk of dementia compared with those with faster walking speeds.[10] In addition, other researchers reported that

Correspondence: Suguru Ando, Department of Physical Therapy, Faculty of Health Science, Aino University, 4-5-4 Higashioda, Ibaraki City, Osaka 567-0012, Japan.
Tel.: +81-72-627-1711.
Fax: +81-72-627-1753.
E-mail: s-ando@pt-u.aino.ac.jp

Key words: higher-level functional capacity, usage of technology, community-dwelling older adults.

Contributions: SA, contributed to research collaboration with Ibaraki City, conducted the analysis, and took responsibility for the article, overseeing all communication from submission to publication; MI, organized the data files and conducted the analysis; YY, KS, WN, were involved in the analysis process. All authors made substantial contributions to the manuscript and approved its content.

Conflict of interest: the authors declare that there is no conflict of interest regarding the publication of this article.

Ethics approval and consent to participate: the study protocol, approved by the Ethics Committee of the Faculty of Health Science at Aino University (Ref. No. 2019-011), adhered to the principles outlined in the Helsinki Declaration of Human Rights.

Patient consent for publication: participants' informed consent was obtained.

Funding: none.

Availability of data and materials: data and materials are available from the corresponding author upon request.

Conference presentation: this manuscript was developed by incorporating data and presented orally at the 9th Annual Conference of Japanese Community-based Comprehensive Physical Therapy held in Japan in 2022. The presentation was titled "Association between decreased walking speed in community-dwelling older adults and higher-level functional capacity".

Acknowledgments: the authors would like to thank the participants of our study and the Ibaraki City Office for their assistance with participant recruitment.

Received: 16 May 2024.
Accepted: 2 August 2024.


*Licensee PAGEPress, Italy*
*Geriatric Care 2024; 10:12670*
*doi:10.4081/gc.2024.12670*

older adults with walking speeds faster than 0.92 m/s were free of dementia.[11] Therefore, a walking speed of 1.0 m/s has been established as the reference value for dysfunction and disability. A systematic review of walking speed also revealed that individuals who walked faster than 1.0 m/s generally had lower risks of persistent lower extremity limitation, mobility disability, ADL disabilities, falls, institutionalization or hospitalization, and mortality.[12]

Higher-level functional capacity encompasses instrumental ADL, effectance, and social roles, identified by Lawton as essential components reflecting older adults' refined life competencies necessary for preserving autonomy within their societal milieu.[13] This capacity is assessed using indices such as the Japan Science and Technology Agency Index of Competence (JST-IC),[14,15] administered *via* questionnaires. Specifically, the JST-IC measures aspects like the use of new devices, social contribution, and social participation tailored to the current lifestyle of Japanese older adults. These indices, along with their aggregated and subscale scores, serve as evaluative tools,[16] offering nuanced insights into higher-level functional capacity.

Despite these advancements, limited research explores the relationship between these functional capacity subscales and walking speed, a crucial health indicator. Understanding this relationship can facilitate multidimensional considerations for the development of preventive interventions and rehabilitation programs tailored to older adults. While there have been reports indicating no significant differences between genders in higher-level functional capacity,[14,15] it is evident that there is a distinct gender gap in walking speed.[17] Therefore, understanding how higher-level functional capacity relates to walking speed requires careful consideration of gender differences, particularly among older women responsible for household duties.

This study aimed to investigate the relationship between walking speed, considering general cut-off values, and higher-level functional capacity, including its subscales, in community-dwelling older women.

## Materials and Methods

### Participants

We recruited 110 community-dwelling women *via* local newspaper advertisements. Data collection occurred between August and December 2019 at the Ibaraki City Healthcare Center. The exclusion criteria encompassed individuals exhibiting obvious cognitive dysfunction and those unable to walk independently. Among the initial 110 women enrolled, we excluded 19 patients for the following reasons: age <65 years (n=17), no body weight data (n=1), and no grip strength data (n=1). A flowchart illustrating the participant selection process is presented in Figure 1. Our analysis focused on 91 community-dwelling women aged 65 years and older (mean age, 78.7±7.1 years). The sample size was calculated using G*Power 3.1.9.2; 106 participants were required to achieve a power of 0.80, with an effect size (d) of 0.5 and α set at 0.05. The study protocol, approved by the Ethics Committee of the Faculty of Health Science at Aino University (Ref. No. 2019-011), adhered to the principles outlined in the Helsinki Declaration of Human Rights. All participants provided informed consent by reading and signing the consent form approved by the Institutional Review Board.

### Basic characteristics

The participants' basic characteristics, higher-level functional capacities, and physical functions were assessed. Basic characteristics included age, height, weight, body mass index (BMI), current medical history (hypertension, hyperlipidemia, or diabetes), certification of required support, cognitive function, and mood status. Certification of Required Support is a system within Japan's Long-Term Care Insurance System that is used to assess whether older adults or disabled individuals can live independently and the support they need. Cognitive function and depressed mood were evaluated using relevant items from the Kihon checklist (KCL).[18] Participants were said to have cognitive decline when they answered negatively to one or more of the three questions (yes or no) in KCL numbers 18 to 20, referred to as KCL-cognitive function.

The questions were as follows: i) "do your family or friends point out your memory loss? For example, you ask the same question repeatedly" (yes); ii) "do you look up phone numbers when making a call?" (no); and iii) "do you find yourself not knowing today's date?" (yes). Individuals indicating affirmation to two or more questions out of the five yes/no questions in KCL numbers 21 to 25 were identified as having a depressed mood. The questions were as follows: i) "in the last 2 weeks, have you felt a lack of fulfillment in your daily life?" (yes); ii) "in the last 2 weeks, have you felt a lack of joy when doing the things you used to enjoy?" (yes); iii) "in the last 2 weeks, have you felt difficulty in doing what you could easily do before?" (yes); iv) "in the last 2 weeks, have you felt helpless?" (yes); and v) "in the last 2 weeks, have you felt tired without reason?" (yes).

### Assessment of higher-level functional capacity

The JST-IC questionnaire was employed to evaluate higher-level functional capacity. It comprises 16 items across four subscales. The JST-IC was developed based on the Tokyo Metropolitan Institute of Gerontology Index of Competence. These subscales encompass the usage of technology, collecting information, health literacy, daily life management, and social participation. The "usage of technology" subscale gauges proficiency in utilizing modern equipment in daily routines. "Collecting information and health literacy" assesses the ability to gather and apply information to improve quality of life. "Daily life management" evaluates the capacity to manage one's own life as well as that of family and others. Lastly, "social participation" measures involvement in local activities and community roles. Scoring ranges are as follows: total score (0-16) comprising usage of technology (0-4), collecting information and health literacy (0-4), daily life management (0-4), and social participation (0-4). Higher scores denote greater competence in the respective areas.

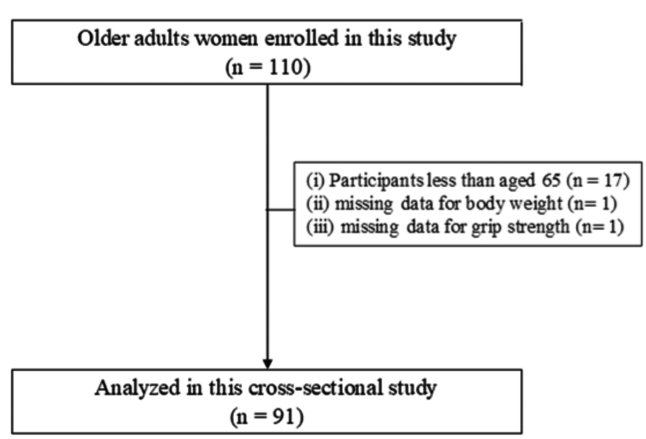


Figure 1. Participant flowchart.

## Assessment of physical functions and bone mineral density

The physical functions of the participants were evaluated according to grip strength and walking speed. Grip strength, which serves as an indicator of overall muscular strength, was assessed by measuring it twice for each hand while the participant maintained a standing position. A dynamometer (Digital Handgrip Meter KEEPs, MACROSS Inc., Tokyo, Japan) was utilized for these measurements, and the maximum value obtained was recorded as the representative value.[19] Walking speed was determined by measuring the time it took participants to traverse a 6-meter straight path at a comfortable pace. To ensure accurate measurement, 1-meter acceleration, and deceleration paths were established at both ends of the 6-meter walking path.[20] Walking speed was then recorded using a stopwatch.

Bone mineral density was measured using a quantitative ultrasound device (CM-300, Furuno, Hyogo, Japan) within a temperature-controlled environment (25-27°C). The young adult mean (YAM, %) at the right calcaneus was analyzed as a parameter of the quantitative ultrasound device while participants were in a seated position. YAM represented an individual's bone mass as a percentage of the average bone mass for healthy young adults aged 20-44 years, standardized to 100.

## Statistical analysis

Statistical analyses were performed using SPSS software (version 28, SPSS for Windows, IBM Japan Corporation, Tokyo, Japan). The Shapiro-Wilk test was used to assess the distributions of continuous variables. Values are presented as mean ± standard deviation, median (interquartile range), or frequency (percentage). First, we categorized the participants into two groups based on their walking speeds: those faster and those slower than 1.0 m/s. Second, we compared the differences in walking speed using the Mann-Whitney U test for continuous data and Fisher's exact test for categorical data. Finally, we performed a logistic regression analysis with walking speed as the dependent variable and each measurement item as an independent variable, after adjusting for age, BMI, and the presence of certification of required support. Statistical significance was set at less than 5%.

# Results

Table 1 presents the results of the two-group comparison. The group with a walking speed of ≥1.0 m/s had 55 (60.4%) participants, whereas the group with a walking speed of <1.0 m/s had 36 (39.6%) participants. Participants in the group with a walking speed <1.0 m/s were significantly older and had higher rates of medication use, cognitive decline, depressed mood, and certification of required support. They also had significantly lower grip strength and bone mineral density. In the JST-IC subscale, the slower walking speed group had significantly lower values in all domains except the collecting information and health literacy domains.

Table 2 presents the results of the logistic regression analysis. Grip strength [odds ratio (OR), 0.84; 95% confidence interval (CI), 0.713-0.992], the total score of the JST-IC (OR, 0.82; 95% CI, 0.675-0.997), and usage of technology (OR, 0.54; 95% CI, 0.309-0.958) were significant factors associated with slower walking speed.

# Discussion

Our study revealed that grip strength and higher-level functional capacity, specifically the usage of the technology subscale, were associated with slower walking speeds among community-dwelling older women. In this study, slower walking speed was significantly associated with low JST-IC scores, consistent with the findings of a previous study.[21] Participants with walking speeds faster and slower than 1.0 m/s had mean scores of 11.4 and 8.0, respectively, on the JST-IC subscale. Iwasa *et al.* reported an overall JST-IC score of 7.7



**Table 1.** Simple comparison of participant's characteristics and variables.

| Variables | | All participant (n=91) | | Walking speed ≥1.0 m/s (n=55) | | Walking speed <1.0 m/s (n=36) | | p |
|---|---|---|---|---|---|---|---|---|
| Age (years) | | 78.7 | ±7.1 | 75.8 | ±6.3 | 83.3 | ±5.7 | <0.001 |
| Height (cm) | | 151.6 | ±5.5 | 153.0 | ±5.5 | 149.4 | ±5.0 | 0.002 |
| Weight (kg) | | 53.2 | ±8.7 | 53.1 | ±7.8 | 53.3 | ±10.0 | 0.950 |
| BMI (kg/m²) | | 23.1 | ±3.5 | 22.7 | ±3.0 | 23.8 | ±4.2 | 0.163 |
| Medical history | Hypertension, n (%) | 38 | (41.8) | 19 | (34.5) | 19 | (52.8) | 0.128 |
| | Hyperlipidemia, n (%) | 9 | (9.9) | 6 | (10.9) | 3 | (8.3) | 1.000 |
| | Diabetes mellitus, n (%) | 9 | (9.9) | 3 | (5.5) | 6 | (17) | 0.147 |
| Medication (n/day), median | | 2.0 | (2.0-3.0) | 2.0 | (1.0-3.0) | 3.0 | (2.0-4.0) | <0.001 |
| Cognitive decline, n (%) | | 32 | (35.2) | 14 | (25.5) | 18 | (50.0) | 0.024 |
| Depressed mood, n (%) | | 27 | (29.7) | 9 | (16.4) | 18 | (50.0) | 0.001 |
| Certification of required support, n (%) | | 30 | (33.0) | 7 | (12.7) | 13 | (63.9) | <0.001 |
| Grip strength (kg) | | 20.2 | ±4.8 | 21.9 | ±4.8 | 17.5 | ±3.2 | <0.001 |
| YAM (%), median 6 | | 4.0 | (59.0-70.0) | 68.0 | (60.0-73.0) | 61.0 | (59.0-67.5) | 0.022 |
| JST-IC total (score) | | 9.8 | ±3.4 | 11.4 | ±3.2 | 8.0 | ±3.0 | <0.001 |
| Usage of technology (score), median | | 3.0 | (2.0-4.0) | 3.0 | (3.0-4.0) | 2.0 | (1.0-3.0) | <0.001 |
| Collecting information and health literacy (score), median | | 3.0 | (3.0-4.0) | 4.0 | (3.0-4.0) | 3.0 | (2.0-4.0) | 0.094 |
| Daily life management (score), median | | 3.0 | (2.0-4.0) | 3.0 | (2.0-4.0) | 2.0 | (2.0-3.0) | 0.003 |
| Social participation (score), median | | 1.0 | (0.0-2.0) | 1.0 | (0.0-3.0) | 0.0 | (0.0-1.0) | 0.001 |

BMI, body mass index; YAM, young adult mean; JST-IC, Japan Science and Technology Agency Index of Competence. Values are presented as mean ± standard deviation, median (interquartile range), or frequency (percentage). P-values were based on the Mann-Whitney U test for continuous measures and Fisher's exact test for proportions.

for older women aged 75-84 years.[15] Total JST-IC scores for older women with walking speeds slower than 1.0 m/s were closer to the reference values.

The only JST-IC subscale associated with walking speed was the usage of technology, indicating proficiency in using new daily life equipment [operating a mobile phone, using an automated teller machine (ATM), operating a video recorder, and sending emails *via* mobile or computer].[22] Hierarchical menus, frequently utilized in devices like mobile phones and ATMs, play a crucial role in reflecting instrumental ADL in the higher-level functional capacity.[23] They organize functions into groups and categorize them under clear headings, allowing many options to fit into a small screen. Users can easily reach a desired function by sequentially selecting the menu items in each hierarchy from the highest level. Compared with younger people, older adults experience a decline in their ability to manipulate hierarchical menus.[24]

Proficiency in using technology's hierarchical menus demands high cognitive function and spatial perception.[25,26] Gale *et al.* revealed an association between decreased walking speed and decreased performance in the frontal lobe functions, such as executive functions and processing speed.[27] Spatial perception involves mobilizing and integrating many senses, including visual, auditory, vestibular, and somatosensory, to represent a three-dimensional external space in the brain.[28] According to Kitanishi *et al*., spatial perception is processed in the hippocampus, which is responsible for memory and the transmission of information to the lower regions.[29] Anson *et al*. demonstrated that vestibular signals are involved in spatial and temporal aspects of walking *via* posture-supporting balance.[30] The usage of technology does not require high physical activity; however, we inferred that decreased frontal lobe function and spatial perception, which are necessary to operate equipment, affected the decrease in walking speed.

Our study found that participants with walking speeds slower than 1.0 m/s had a mean grip strength of 17.5 kg. This aligns with sarcopenia characteristics in women, where walking speeds slower than 1.0 m/s and grip strength below 18 kg are reference values.[3] Thus, the interrelationship between these indicators was anticipated. Walking speed correlates more strongly with muscle strength, serving as a practical and convenient gauge for identifying declining physical function and impending sarcopenia in older adults.

This study had some limitations. First, our results only indicated a relationship and not a causal relationship because our study was based on cross-sectional data. Therefore, future longitudinal studies must examine the relationship reported in the results in detail. Second, owing to the study's small sample size, multivariate analysis was performed using each measurement item as an independent variable. Therefore, analyzing all measurement items together as independent variables was impossible. Third, the results may not be adaptable to other community-dwelling older women or the municipality because the study area was only a specific local city district. However, the average JST-IC total score of the participants in our study was comparable with the average score in a previous study,[14] and the participants in our study were older adults with generally higher-level functional capacity. Fourth, we did not assess upper extremity functions, executive functions, processing speed, and spatial perception related to the usage of technology. In the future, we must assess upper extremity motor and neuropsychological functions, such as the trail-making test, to investigate the detailed abilities required to use new technology. Fifth, using only 1.0 m/s as the sole cut-off value for walking speed could be somewhat arbitrary. As demonstrated in our introduction, there are various cut-off values for walking speed. Therefore, conducting sensitivity analyses to investigate the results may render them more robust. Sixth, it is important to address the difficulties faced in conducting routine health assessments in general healthcare settings that are not specialized in gerontology. Such settings often lack the specific tools and methods needed to evaluate the unique health issues and functional decline of older adults. Consequently, the data obtained from these assessments may not fully represent older adults. Furthermore, implementing comprehensive functional assessments in everyday medical practice is often constrained by limited resources and time. Recognizing these limitations is crucial when interpreting our study results and planning future research and healthcare strategies for older adults.

## Conclusions

In summary, we investigated the association between walking speed and higher-level functional capacity using the JST-IC in community-dwelling older women. Technology was associated with decreased walking speed. The use of technology does not require high activity; however, executive functions and processing speed are required for operation. Moreover, spatial perception may play a role in posture-mediated walking ability.



**Table 2.** Logistic regression analysis with walking speed as the dependent variable.

| Variables | | Adjusted OR (95% CI) | | p |
|---|---|---|---|---|
| Medical history | Hypertension | 1.214 | (0.391-3.773) | 0.737 |
| | Hyperlipidemia | 1.464 | (0.260-8.242) | 0.665 |
| | Diabetes mellitus | 2.363 | (0.307-18.176) | 0.465 |
| Medication | | 1.571 | (0.936-2.635) | 0.087 |
| Cognitive decline | | 2.082 | (0.641-6.759) | 0.222 |
| Depression | | 2.904 | (0.824-10.229) | 0.097 |
| Grip strength | | 0.841 | (0.713-0.992) | 0.040 |
| YAM | | 0.982 | (0.905-1.067) | 0.671 |
| JST-IC total | | 0.820 | (0.675-0.997) | 0.046 |
| Usage of technology | | 0.544 | (0.309-0.958) | 0.035 |
| Collecting information and health literacy | | 0.709 | (0.413-1.215) | 0.210 |
| Daily life management | | 0.877 | (0.500-1.540) | 0.649 |
| Social participation | | 0.669 | (0.412-1.087) | 0.105 |

OR, odds ratio; CI, confidence interval; YAM, young adult mean; JST-IC, Japan Science and Technology Agency Index of Competence. We used logistic regression analysis to obtain age, body mass index, and certification of required support-adjusted odds ratio for factors related to walking speed. The independent variable was analyzed one at a time without simultaneously analyzing the measured items.

## References

1. Middleton SL, Fritz S, Lusardi M. Walking speed: the functional vital sign. J Aging Phys Act 2015;23:314-22.
2. Ostir GV, Kuo YF, Berges IM, et al. Measures of lower body function and risk of mortality over 7 years of follow-up. Am J Epidemiol 2007;166:599-605.
3. Chen LK, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc 2020;21:300-7.e2.
4. Satake S, Arai H. The revised Japanese version of the cardiovascular health study criteria (revised J-CHS criteria). Geriatr Gerontol Int 2020;20:992-3.
5. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001;56:M146-56.
6. Vermeulen J, Neyens JC, van Rossum E, et al. Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. BMC Geriatr 2011;11:33.
7. Perera S, Patel KV, Rosano C, et al. Gait speed predicts incident disability: a pooled analysis. J Gerontol A Biol Sci Med Sci 2016;71:63-71.
8. Quach L, Galica AM, Jones RN, et al. The nonlinear relationship between gait speed and falls: the maintenance of balance, independent living, intellect, and zest in the elderly of Boston study. J Am Geriatr Soc 2011;59:1069-1073.
9. Middleton A, Fulk GD, Herter TM, et al. Self-selected and maximal walking speeds provide greater insight into fall status than walking speed reserve among community-dwelling older adults. Am J Phys Med Rehabil 2016;95:475-482.
10. Dumurgier J, Artaud F, Touraine C, et al. Gait speed and decline in gait speed as predictors of incident dementia. J Gerontol A Biol Sci Med Sci 2017;72:655-61.
11. Abellan van Kan G, Rolland Y, Gillette-Guyonnet S, et al. Gait speed, body composition, and dementia. The EPIDOS-Toulouse cohort. J Gerontol A Biol Sci Med Sci 2012;67:425-32.
12. Abellan van Kan G, Rolland Y, Andrieu Y, et al. Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) task force. J Nutr Health Aging 2009;13:881-9.
13. Lawton MP. Assessing the competence of older people. In: Kent DP, Kastenbaum R, Sherwood S, eds. Research, planning, and action for elderly: the power and potential of social science. New York, USA: Behavioral Publications; 1972. pp 122-43.
14. Iwasa H, Masui Y, Inagaki H, et al. Development of the Japan science and technology agency index of competence to assess functional capacity in older adults: conceptual definitions and preliminary items. Gerontol Geriatr Med 2015;1: 2333721415609490.
15. Iwasa H, Masui Y, Inagaki H, et al. Assessing competence at a higher level among older adults: development of the Japan science and technology agency index of competence (JST-IC). Aging Clin Exp Res 2018;30:383-93.
16. Kameyama K, Tsutou A, Fujino H. The relationship between health-related quality of life and higher-level functional capacity in elderly women with mild cognitive impairment. J Phys Ther Sci 2016;28:1312-7.
17. Ko SU, Tolea MI, Hausdorff JM, Ferrucci L. Sex-specific differences in gait patterns of healthy older adults: results from the Baltimore longitudinal study of aging. J Biomech 2011;44:1974-9.
18. Fukutomi E, Okumiya K, Wada T, et al. Relationships between each category of 25-item frailty risk assessment (Kihon Checklist) and newly certified older adults under long-term care insurance: a 24-month follow-up study in a rural community in Japan. Geriatr Gerontol Int 2015;15:864-71.
19. Isen J, McGue M, Iacono W. Genetic influences on the development of grip strength in adolescence. Am J Phys Anthropol 2014;154:189-200.
20. Muir-Hunter SW, Clark J, McLean S, et al. Identifying balance and fall risk in community-dwelling older women: the effect of executive function on postural control. Physiother Can 2014; 66:179-86.
21. Shoji T, Fujii Y, Tateoka K, et al. The association of the Japan science and technology agency index of competence with physical and cognitive function in community-dwelling older adults. Geriatr Gerontol Int 2022;22:753-8.
22. Suzuki T. Health status of older adults living in the community in Japan: recent changes and significance in the super-aged society. Geriatr Gerontol Int 2018;18:667-77.
23. Karimov J, Ozbayoglu M, Tavli B, Dogdu E. Menu optimization for multi-profile customer systems on large scale data. Comput Econ 2022;60:221-42.
24. Zhou J, Rau PLP, Salvendy G. Use and design of handheld computers for older adults: a review and appraisal. Int J Hum Comput Interact 2012;28:799-826.
25. Saho K, Uemura K, Fujimoto M, Matsumoto M. Evaluation of higher-level instrumental activities of daily living via micro-doppler radar sensing of sit-to-stand-to-sit movement. IEEE J Transl Eng Health Med 2020;8:2100211.
26. Ziefle M, Bay S. How to overcome disorientation in mobile phone menus: a comparison of two different types of navigation aids. Hum-Comput Interact 2006;21:393-433.
27. Gale CR, Allerhand M, Sayer AA, et al. The dynamic relationship between cognitive function and walking speed: the English longitudinal study of ageing. Age 2014;36:9682.
28. Eimer M. Multisensory integration: how visual experience shapes spatial perception. Curr Biol 2004;14:R115-7.
29. Kitanishi T, Umaba R, Mizuseki K. Robust information routing by dorsal subiculum neurons. Sci Adv 2021;7:eabf1913.
30. Anson E, Pineault K, Bair W, et al. Reduced vestibular function is associated with longer, slower steps in healthy adults during normal speed walking. Gait Posture 2019;68:340-5.