showed a similar pattern of association of lower leg fractures with BMI (data not shown). In the present study, a high BMI was a significant risk factor for humerus fractures and this persisted after adjustment for BMD. The finding is consistent with a recent short-term (1 year) prospective analysis in 832,775 Spanish women aged 50 years or more visiting general practitioners (SIDIAP),[16] in which a protective effect of obesity was found on future hip fracture and forearm fracture (relative risk [RR] = 0.49; 95% CI, 0.44–0.55, and RR = 0.83; 95% CI, 0.75–0.91, respectively), but obese women were at significantly higher risk of future proximal humeral fracture than the rest of the study population (RR = 1.28; 95% CI, 1.04–1.58). These findings are also consistent with an earlier report that obese women had a higher prevalence of a prior humeral fracture (odds ratio [OR] = 3.48; 95% CI, 0.18–6.68).[56] The reasons for the site-specific association between high BMI and humeral fracture risk are not known, though it may conceivably reflect a different pattern of falling or a greater load upon bones in the upper extremity in falls among the obese population. Moreover, a different padding effect of the soft tissues in different skeletal regions may produce diverse energy dissipation after trauma and, therefore, a different protection of the underlying bone.

Our results are at first sight at variance with the conclusions of Compston and colleagues,[15] who state that that obesity is not protective against fracture in postmenopausal women. That study, however, included a large number of non-adjudicated ankle and tibial fractures. Ankle fractures are not generally regarded as being associated with osteoporosis[51,56] and, as implied above, the accuracy of a self-reported distinction between ankle and other lower leg fractures is questionable. In their report, ankle fractures were significantly more frequent in obese compared with non-obese women. Given that the incidence of forearm, hip, pelvic, upper leg, and spine fractures was higher in underweight women than in obese women, their report is not inconsistent with our findings. Moreover, the present study also found a protective effect of low BMI for future lower leg fracture.

The question arises whether our findings have implications for the Fracture Risk Assessment Tool (FRAX®), which predicts the probability of a hip and a major fracture based on clinical risk factors such as sex, age, BMI, previous fracture, family history, glucocorticoid use, smoking, alcohol use, and secondary osteoporosis.[57] BMI is used as a continuous variable in FRAX, and BMD can be optionally entered into the model. Data from the meta-analysis of De Laet and colleagues[11] were used in the construct of FRAX. The association between BMI and the risk of hip fracture and other osteoporotic fractures in the present study is nearly identical to that described by De Laet and colleagues[11] in the absence of BMD. After adjustment for BMD, the risk of hip fracture associated with low BMI was attenuated in the same way as that described.[11] In the case of osteoporotic fractures, we have shown a slight though significant increase in risk with increasing BMI (see Table 6). This finding is consistent with the earlier meta-analysis, though the increase in risk was not statistically significant because of the smaller sample size. These considerations indicate that modifications of the FRAX algorithm are not warranted based on the present analysis; a view consistent with a recent report from the SOF study that FRAX is of value predicting fractures in obese women, particularly when used with BMD.[58]

The present study has several limitations, some of which we have discussed. These include the limited sampling frame for BMD measurements, inaccuracies in the estimate of BMD in the presence of a high fat mass, and uncertainties in the coding of some fractures. With regard to the first limitation, our results were similar when HRs not adjusted for BMD were calculated in those 27% of women in whom BMD was measured. The different settings of the cohorts are also a limitation, but that would weaken, not strengthen, an association between BMI and fracture. Conversely, the different settings increase the generalizability of our findings. The greatest limitation is that the present analysis is confined to women. Several lines of evidence suggest that the relationship between BMI and fracture risk may differ in men.[11,59]

A limitation in the understanding of possible mechanisms is that we have not been able to examine all potential confounding factors (eg, smoking, previous fracture, alcohol, comorbidities). Of possible relevance is the association of type 2 diabetes with high BMI. In a recent large clinical database in Manitoba, Canada, individuals with diabetes had a BMI approximately 3 kg/m^2 higher than those without diabetes.[60] Of particular interest, diabetes was associated with a 60% increased risk for major osteoporotic fracture when adjusted for clinical risk factors for fracture including BMI and BMD (HR = 1.61; 95% CI, 1.42–1.83). Thus, the higher risk for osteoporotic fracture for obese women (BMI 35 kg/m^2 versus 25 kg/m^2) in this report could be related in part to diabetes. Diabetic status was recorded in the present analysis for only 9% of women. In the women that had information on diabetes, the prevalence of diabetes was 3.4% in women with a normal BMI and 6.7% in obese women (data not shown). The small size of the available sample meant that we were unable to examine the impact of diabetes on the relationship between BMI and future fracture risk in more detail. The age interactions, the result with and without BMD and some of the fracture-specific findings might suggest an important role for low physical function and frailty in explaining these associations; but, as was the case for diabetes, we were unable to examine this further.

With these caveats, we conclude that low BMI remains an important clinical risk factor for hip and all osteoporotic fractures combined and that obesity in women is associated with a significant, albeit modest, reduction in fracture risk. In contrast, obese postmenopausal women appear to be at higher risk for humeral fractures than those with normal BMI. Moreover, after adjustment for BMD there is a slight increase in osteoporotic fracture risk with increasing BMI.

Disclosures

All authors state that they have no conflicts of interest.

Acknowledgments

HJ was supported by an ESCEO-AMGEN Osteoporosis Fellowship Award. Amgen had no input into the analysis plan or in the writing of this report. The EPIC-Norfolk study is supported by the Medical Research Council UK (G0401527) and Cancer Research UK (8257). CPRD has received funding from the MHRA, Wellcome Trust, Medical Research Council, NIHR Health Technology Assessment program, Innovative Medicine Initiative, UK Department of Health, Technology Strategy Board, Seventh Framework Programme EU, various universities, contract research organizations, and pharmaceutical companies. The Department of Pharmacoepidemiology & Pharmacotherapy, Utrecht Institute for Pharmaceutical Sciences has received unrestricted funding for pharmacoepidemiological research from GlaxoSmithKline, Novo Nordisk, the private-public funded Top Institute Pharma (www.tipharma.nl; includes co-funding from universities, government, and industry), the Dutch Medicines Evaluation Board, and the Dutch Ministry of Health. The AHS has been conducted at the Radiation Effects Research Foundation (RERF), Hiroshima and Nagasaki, Japan, which is a private, nonprofit foundation funded by the Japanese Ministry of Health, Labour and Welfare (MHLW) and the U.S. Department of Energy (DOE), the latter in part through DOE Award DE-HS0000031 to the National Academy of Sciences. The ECOSAP Study was sponsored by Eli Lilly. The Rochester study was supported by the National Institute of Musculoskeletal and Skin Diseases (R01 AR27065), U.S. Public Health Service. CaMOS was funded by the Canadian Institutes for Health Research with contributions from pharmaceutical and other entities who made no contribution to the study design or execution.

Authors' roles: Study design: HJ, AO, JAK, and EMC. Study conduct: HJ, AO, JAK, and EMC. Data collection: RDC, CC, SRC, ADP, JAE, SF, CCG, DG, DH, KTK, MAK, HK, AZL, EL, WBL, DM, LJM, TWON, JAP, MCZ, FR, JCP, DMR, TvS, and NY. Data analysis: HJ. Data interpretation: HJ, AO, JAK, and EMC. Drafting manuscript: HJ, JAK, and EMC. Revising manuscript content: HJ, AO, JAK, EMC, RDC, CC, SRC, ADP, JAE, SF, CCG, DG, DH, KTK, MAK, HK, AZL, EL, WBL, DM, LJM, TWON, JAP, MCZ, FR, JCP, DMR, TvS, and NY. Approving final version of manuscript: HJ, AO, JAK, EMC, RDC, CC, SRC, ADP, JAE, SF, DG, CCG, DH, KTK, MAK, HK, AZL, EL, WBL, DM, LJM, TWON, JAP, MCZ, FR, JCP, DMR, TvS, and NY. HJ takes responsibility for the integrity of the data analysis.

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BMJ open

Performance-based assessments and demand for personal care in older Japanese people: a cross-sectional study

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To cite: Shimada H, Suzuki T, Suzukawa M, *et al.* Performance-based assessments and demand for personal care in older Japanese people: a cross-sectional study. *BMJ Open* 2013;**3**:e002424. doi:10.1136/bmjopen-2012-002424

▸ Prepublication history for this paper are available online. To view these files please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2012-002424).

Received 30 November 2012
Revised 12 March 2013
Accepted 18 March 2013

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ABSTRACT

Objectives: To identify appropriate clinical tests for determining the demand for personal care in older Japanese people.

Design: Cross-sectional observation study.

Setting: Obu Study of Health Promotion for the Elderly (Obu, Aichi) and Tsukui Ordered Useful Care for Health (241 day-care centres) cohorts in Japan.

Participants: A total of 10 351 individuals aged 65 years or older (6791 with personal care and 3560 without personal care) participated in the study.

Measures: Physical performance tests included grip strength, the chair stand test, walking speed at a comfortable pace, and the timed up-and-go test. Personal care was defined as participants who had been certified in the national social long-term care insurance in Japan.

Results: Individuals who received personal care showed a significantly poorer performance than those without personal care for all physical performance tests ($p<0.001$). Gait speed was the most useful of the physical performance tests to determine the demand for personal care (receiver operating characteristic curve statistics: men, 0.92; women, 0.94; sensitivity: men, 86; women, 90; specificity: men, 85; women, 85). After adjustment for age, sex, cognitive impairment and other physical tests, all physical performance tests were individually associated with the demand for personal care. A slow gait speed (<1 m/s) was more strongly correlated with the demand for personal care than other performance measures (gait speed OR: 5.9; 95% CI: 5.0 to 6.9).

Conclusions: Clinical tests of physical performance are associated with the demand for personal care in older people. Preventive strategies to maintain physical independence may be required in older adults who show a gait speed slower than 1 m/s. Further research is necessary to confirm these preliminary results.

ARTICLE SUMMARY

Article focus

- Measures of physical performance may identify older persons with a preclinical stage of disability.
- However, it is unclear which performance test and cut-point are the most useful to screen for risk of functional dependence in older Japanese people.
- The purpose of this study was to identify appropriate clinical tests for determining the risk of functional dependence in older Japanese people.

Key messages

- Clinical tests of physical performance were associated with a functional decline in older people.
- Preventive strategies to avoid personal care may be required in older adults who show a gait speed slower than 1 m/s.

Strengths and limitations of this study

- Strengths of this study include a large sample size and performance-based assessment, which could determine actual physical capacity and predict subsequent physical disability in older people living in the community.
- We analysed cross-sectional data. Therefore, further investigation of the validity of these tests in predicting the risk of disability in older people using a prospective study design is recommended.

INTRODUCTION

Japan is the fastest ageing society on earth and the first large country in the history to have its population start shrinking rapidly from natural causes. The life expectancy of Japanese people (mean age: men, 79.4 years; women, 85.9 years) is at the highest level in the world. The population of Japan, which currently stands at 127 million, is expected to fall to just under 100 million in the next 40 years. By 2050, 4 of 10 adults in Japan will be older than 65 years of age. Japan implemented the national social long-term care insurance (LTCI) system on 1 April 2000. Every Japanese person aged 65 and older is eligible for benefits based strictly on physical and mental frailty or disability.[1] In June 2006, the Japanese government implemented a major LTCI reform that focused on preventive benefits for the population at high risk of disability (ie, physical and/or cognitive frailty), to contain the skyrocketing costs of the LTCI.[2]

Physical frailty increases with advancing age and is a major risk factor for dependency, institutionalisation, and mortality.[3–5] People with a disability have higher healthcare needs and use compared with those without a disability.[6] Although the biggest risk factor for future frailty is advancing age, other factors that are possibly modifiable through interventions should not be ignored. For the purpose of targeting risk factors for future frailty, adequate assessment of individual people may be required. One of the main characteristics of the elderly population is its heterogeneity, with elderly people in the same age range showing a wide variance with regard to their risk of disability. To prevent frailty or disability, population-based intervention programmes should be targeted at the population at risk. A feasible and valid screening tool available for research and clinical settings is required to identify target populations. The Interventions on the Frailty Working Group developed recommendations to screen, recruit, evaluate and retain frail older persons in clinical trials.[7] They reported that most researchers focus on the following domains for identification of physical frailty: mobility, such as lower extremity performance and gait abnormalities; muscle weakness; poor exercise tolerance; unstable balance and factors related to body composition, such as weight loss, malnutrition and muscle loss.[7]

In an effort to select tailored preventive programmes in the Japanese LTCI system, those at high risk for subsequent disability are identified by a basic functional status questionnaire. Although the questionnaire is relatively quick to administer, a performance-based assessment could determine actual physical capacity and more accurately predict subsequent physical disability in community-living older people. Guralnik *et al*[8] reported that measures of physical performance may identify older persons with a preclinical stage of disability who may benefit from interventions to prevent the development of frank disability. A previous study identified that a rapid gait test was more likely than other mobility performance tests to discriminate older women at high risk of frailty based on the Japanese LTCI system.[9] However, which performance tests including upper and lower limb muscle functions and which cut-points are the most useful to screen for the demand for personal care are not clear. This study investigated the relationships between performance-based physical assessments and demand for personal care in older people using two large sample cohorts in Japan.

METHODS

Participants

We performed a national study of 10 351 individuals aged 65 years and older who had received personal care (n=6791) and those who had not received personal care (n=3560). The study included individuals who were enrolled in the Obu Study of Health Promotion for the Elderly (OSHPE) and the Tsukui Ordered Useful Care for Health (TOUCH) programme. To enrol in the OSHPE, an individual was recruited from Obu, Japan, which is a residential suburb of Nagoya. Inclusion criteria required that the participant was aged 65 years or older at examination in 2011 or 2012, lived in Obu, and had not participated in another study. Exclusion criteria stipulated that participants be certified as needing support or care by the Japanese public LTCI system, had disability in basic activities of daily living, and could not carry out performance-based assessments. To enrol in the TOUCH programme, an individual had to be 65 years or older and certified as needing support or care from the Japanese public LTCI system. Detailed information was provided in a previous study.[10] In brief, TOUCH sites (241 day-care centres) are located throughout Japan and provide comprehensive, facility-based day-care services (eg, bath, lunch, physical and cognitive recreational activities and physical exercise). Most TOUCH clients have some physical disability and frailty, defined as the presence of weakness, low physical activity and/or slow gait speed, in accordance with the widely accepted definition of frailty.[7]

A total of 10 351 older participants (mean age, 78.8±8.0 years) underwent performance-based assessments. Informed consent was obtained from all participants prior to their inclusion in the study, and the Ethics Committee of the National Centre for Geriatrics and Gerontology approved the study protocol.

Performance-based assessment

The assessment measures were conducted by well-trained staff who had nursing, physiotherapy, occupational therapy or similar qualifications. Prior to start of the study, all staff received training from the authors in the correct protocols for administering all of the assessment measures. The assessment included several physical tests. Upper and lower limb muscle functions were assessed with the grip strength (GS) and the chair stand test (CST), respectively.[11] Gait function was assessed with walking time tests conducted at a comfortable pace (comfortable walking speed, CWS) and with the timed up-and-go (TUG) test.[12]

GS was measured in kilograms in the participant's dominant hand using a Smedley-type handheld dynamometer (GRIP-D; Takei Ltd, Niigata, Japan). The CST involved sitting down and standing up five times, using a chair without an armrest. The score was the time taken to complete the task in seconds. Participants were asked to exert their maximum effort in GS and CST. CWS was measured in seconds with a stopwatch. Participants were asked to walk on a flat and straight surface at their CWS. Two markers were used to indicate the start and end of the path, and a 2 m and over approach was allowed before reaching the start marker so that participants can walk at their comfortable pace within the timed path. They were instructed to continue walking past the end of the path for a further 2 m and over to ensure that the walking pace was consistent throughout the task. The TUG test involved rising from a chair, walking 3 m, turning around, walking back to the chair and sitting down.[12] The TUG test is one of the most frequently used tests of balance and gait, and is often used to assess fall risk in older people.[13] The time to complete the TUG test was measured, in seconds, at each participant's usual pace. Both walking tests were measured once, and if a walking aid was nomally used inside the home, this aid was used during the tests.

Cognitive function

The Mini-Mental State Examination (MMSE)[14] for the OSHPE population and the Mental Status Questionnaire (MSQ) for individuals enrolled in the TOUCH programme were used to measure cognitive functioning, and were used as potential confounders in the association between performance-based physical assessments and functional dependence.[15] Individuals with 23 or fewer points on the MMSE and three or more errors on the MSQ were considered to have cognitive impairment.[15 16]

Statistical analysis

Demographic and clinical variables were compared between the participants with and those without personal care using Student t tests for continuous variables and χ^2 tests for categorical variables. To compare the predictive ability of the study measures, receiver-operated characteristic (ROC) curves were inspected to determine cut-points for each test that best discriminated between the individuals with and those without personal care. Cut-points for maximising the sensitivity and specificity for each test were determined using the Youden index.[17] The area under the curve (AUC), sensitivity and specificity were then calculated for the cut-points. We used multivariate logistic regression analyses to determine ORs and 95% CIs, and to assess independent associations of the cut-points of physical performance measures for demand for personal care. The participants were divided into two groups according to the cut-point of the performance-based physical assessments. Covariates were added sequentially to the logistic model to evaluate the associations at different levels of adjustment. Model 1 included each performance-based physical assessment, and model 2 included the model 1 variables plus age, sex and cognitive impairment as determined by the MMSE or MSQ. Model 3 included all performance-based physical assessments plus age, sex and cognitive impairment. The participants were then divided into five groups as follows: individuals with no risk and those with 1, 2, 3 or 4 risks, according to the number of risks identified by the cut-points of the performance-based physical assessments. The ORs and 95% CIs for the number of risks were calculated adjusted for age, sex and cognitive impairment. All statistical contrasts were made at the 0.05 level of significance, and all data management and statistical computations were performed using the IBM SPSS Statistics V.19.0 software package (SPSS Inc, Chicago, Illinois, USA).

RESULTS

Comparison between participants with and those without personal care

Table 1 shows the characteristics of the participants. The participants with personal care were significantly older ($p<0.001$), included a higher number of women ($p<0.001$) and a higher number of persons with cognitive impairment ($p<0.001$) than those without personal care. For the comparison of performance-based assessments, the participants with personal care had significantly lower scores on all physical tests ($p<0.001$) compared

Table 1 Characteristics of the participants

	Participants with personal care (n=6791)	Participants without personal care (n=3560)
Age (years)*	82.6±6.7	71.8±5.2
Sex, women, n (%)*	4720 (69.5)	1793 (50.4)
Cognitive impairments, n (%)*	2962 (43.6)	562 (15.8) [8]
GS (kg)*	16.3±6.9	27.3±7.8
CST (s)*	13.0±5.6	8.6±2.4
CWS (m/s)*	0.7±0.3	1.2±0.2
TUG (s)*	16.6±7.7	8.9±1.8
Care level in the LTCI, n (%)		
Support need level 1	804 (11.8)	0 (0)
Support need level 2	1112 (16.4)	0 (0)
Care need level 1	2057 (30.3)	0 (0)
Care need level 2	1687 (24.8)	0 (0)
Care need level 3	842 (12.4)	0 (0)
Care need level 4	257 (3.8)	0 (0)
Care need level 5	32 (0.5)	0 (0)
Disability of basic ADLs, n (%)		
Eating	105 (1.5) [136]	0 (0)
Grooming	398 (5.9) [136]	0 (0)
Bathing	1374 (20.2) [136]	0 (0)
Locomotion	745 (11.0) [136]	0 (0)
Stairs	1508 (22.2) [136]	0 (0)

Individuals with 23 or fewer points on the MMSE in the participants without personal care and with three or more errors on the MSQ in the participants with personal care are considered to have cognitive impairment. Beneficiaries of the LTCI can use multiple services for which they are eligible, according to their care plan up to the maximum amount (£382 for Support Level 1; £800 for Support Level 2; £1275 for Care Level 1; £1498 for Care Level 2; £2058 for Care Level 3; £2354 for Care Level 4; £2756 for Care Level 5), in principle, for a 10% copayment and can use more services than covered as long as they pay all the costs for the services beyond the maximum level (calculated at £1=130 yen).
*Comparison between the participants with and without personal care; p<0.001, [ ] missing value.
CST, chair stand test; CWS, comfortable walking speed; GS, grip strength; LTCI, long-term care insurance; MMSE, mini-mental state examination; MSQ, mental status questionnaire; TUG, timed up-and-go test.

Table 2 Cut-points for the risk of demand for personal care and associated sensitivity, specificity, area under the curve (AUC), and OR statistics for all participants

	Criterion	Sensitivity	Specificity	AUC
GS (kg)				
Men	<26	74	89	0.88
Women	<17	80	88	0.90
CST (s)				
Men	≥10	72	74	0.79
Women	≥10	67	77	0.78
CWS (m/s)				
Men	<1.0	86	85	0.92
Women	<1.0	90	85	0.94
TUG (s)				
Men	≥11	76	88	0.88
Women	≥11	79	89	0.90

CST, chair stand test; CWS, comfortable walking speed; GS, grip strength; TUG, timed up-and-go test.

with those in participants without personal care (table 1). The number of participants with and without personal care who used the walking aid during the walking tests were 2593 (38.2%) and 35 (1.0%), respectively.

Cut-points between participants with and those without personal care

ROC curve analysis results, showing the performance cut-points for each test and associated statistics, are shown in table 2. The Youden index determined the cut-points for the demand for personal care as follows: GS in men and women was <26 and <17 kg, respectively; CST was ≥10 s, CWS was <1.0 m/s and TUG was ≥11 s for both sexes. The CWS score had the highest AUC for discriminating the demand for personal care and displayed good sensitivity and specificity (85–90%). High AUCs were also found for GS and TUG, as well as fair to good sensitivity and specificity (74–80%).

Relationships between cut-points and risk of disability

The multiple logistic regression models showed significant relationships between physical performances and the demand for personal care (table 3). The demand for personal care was most closely related to CWS in model 1 (OR=34.7; 95% CI 30.9 to 39.0). These results remained essentially unchanged after controlling for age, sex, cognitive impairment and other physical performance tests. In the final model (model 3), the highest OR of factors related to the demand for personal care was for CWS (OR=5.9; 95% CI 5.0 to 6.9). Figure 1 shows the distribution of CWS for participants with personal care. Participants who walked 1.1 m/s and faster had the lowest amount of personal care (20%). The rate of participants with personal care increased rapidly with a CWS slower than 1.1 m/s, and 90% of participants with a CWS slower than 0.8 m/s had personal care (figure 1A). The rate of functional decline increased rapidly for individuals walking slower than 1 m/s in women (figure 1C) rather than men (figure 1B), and with the rate of functional decline reaching 90% when CWS was slower than 0.8 m/s in both sexes (figure 1B,C).

There was a significant relationship between the number of risks based on the physical performance tests and the demand for personal care. The ORs and 95% CIs for personal care in participants with 1, 2, 3 and 4 risks were 3.1 (2.6 to 3.8), 10.6 (8.7 to 13.1), 35.6 (28.6 to 44.5) and 141.3 (103.6 to 192.7), respectively, compared with participants without risks (p<0.001). Figure 2 shows the distributions of the number of risks for demand for personal care. The rates of participants with personal care who had no risk, 1, 2 and 3 or more risks were 8.7%, 38.5%, 75.6% and 90.0%, respectively (figure 2).

DISCUSSION

Neuromuscular function, including muscle strength, balance and gait, and cognitive function are important risk factors for disability. Performance-based assessment of these factors can be used to identify people at an increased risk of future functional decline. We examined the use of various measures to identify the most useful measure for screening the demand for personal care.

Cut-points of demand for personal care

In the current study, univariate analyses identified all physical tests as being able to discriminate between participants with and those without personal care. When performance was dichotomised for cut-points, GS, CST, CWS and TUG retained statistically significant relationships with personal care. The CWS test (cut-point, 1 m/s) displayed the highest OR in the final model, with good sensitivity and specificity with respect to

Table 3 Relationships between physical performances and the demand for personal care

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
GS (men: <26 vs ≥26 kg, women: <17 vs ≥17 kg)	20.9 (18.6 to 23.5)*	8.5 (7.4 to 9.7)*	4.1 (3.5 to 4.8)*
CST (≥10 vs <10 s)	6.6 (6.1 to 7.3)*	4.1 (3.7 to 4.7)*	1.3 (1.1 to 1.5)*
CWS (<1 vs ≥1 m/s)	34.7 (30.9 to 39.0)*	17.5 (15.3 to 20.0)*	5.9 (5.0 to 6.9)*
TUG (≥11 vs <11 s)	27.1 (24.1 to 30.5)*	15.3 (13.4 to 17.6)*	4.0 (3.4 to 4.8)*

*p<0.01.
Model 1 was crude ORs and Model 2 was adjusted for age, sex and cognitive impairment. Model 3 was adjusted for age, sex, cognitive impairment and physical performances.
CST, chair stand test; CWS, comfortable walking speed; GS, grip strength; TUG, timed up-and-go test.

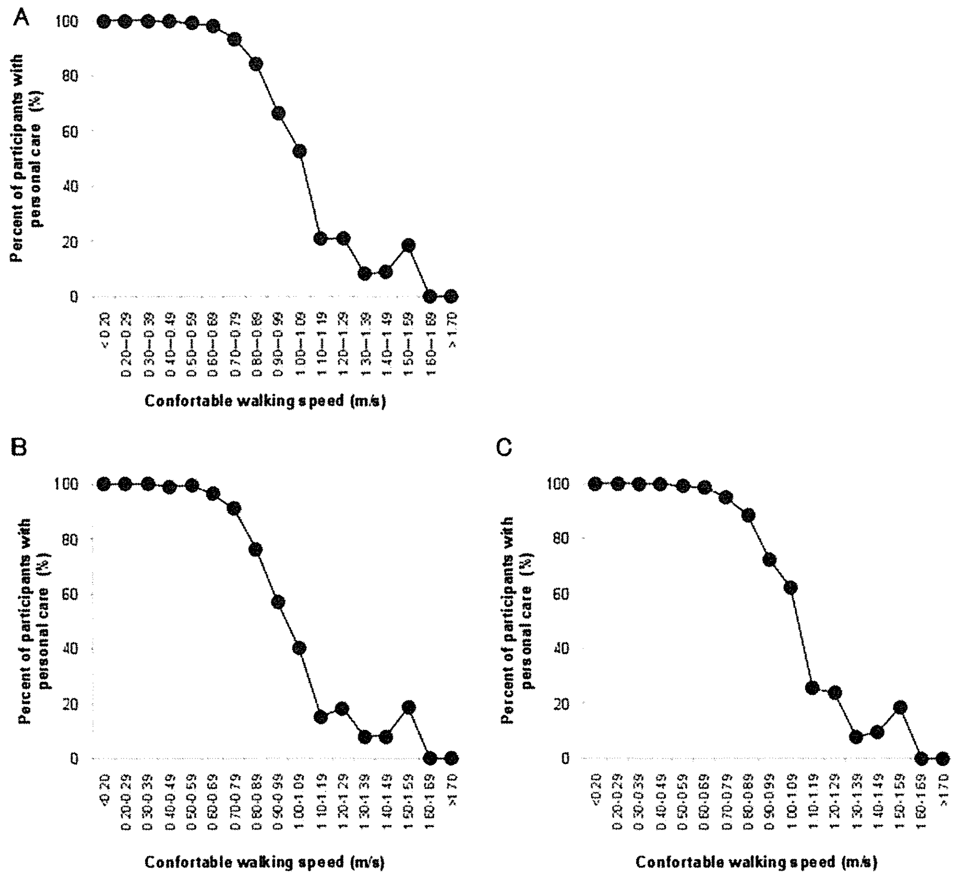

Figure 1 Comfortable walking speed distributions of participants with personal care in all participants (A), men (B) and women (C). The rate of participants with personal care markedly decreased at 1.0 m/s and faster at a comfortable walking speed.

identifying participants with personal care. At identified cut-points, GS (men, 26 kg; women, 17 kg), CST (10 s) and TUG (11 s) could also significantly discriminate participants with personal care with sensitivities and specificities of 67–89%. This result highlights what can occur when dichotomised rather than continuous data are used. There is an associated loss of information and reduced predictive accuracy as a trade-off for ease of scoring and test interpretation. These results, however, are consistent with previous findings that showed associations between measures of muscle strength and mobility and functional decline.[18]

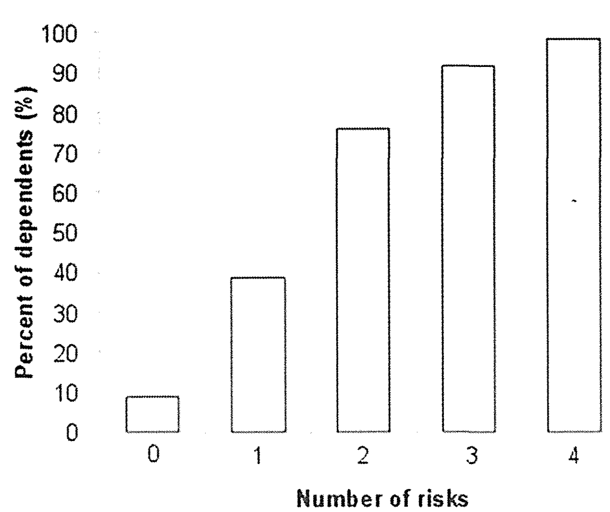

Figure 2 Participants with personal care according to the number of risks identified by cut-points of physical performance tests. Percentages of participants with personal care who had no risk, 1, 2 and 3 or more risks were 8.7%, 38.5%, 75.6% and 90%, respectively.

Gait speed and personal care

Gait velocity, as measured by the CWS test in this study, has been consistently reported to differentiate between participants with and those without personal care, with frail older persons walking significantly slower,[10 19] and has proved to be a strong predictor of adverse events, such as disability,[18 20–25] mortality,[21 22 26 27] hospitalisation[21 22 24 28] and falls.[28 29] Gait slowing, which occurs in the latest stages of life, suggests that mobility is so central to life that energy is shifted away from walking activity only when other vital activities are threatened,[30] which may lead to increased functional independence. In addition, a slower walking speed is an associated factor for subsequent dementia.[31] Dementia is one of the most important factors of health problems for functional decline in the aged population. For our study sample, the cut-point for CWS was 1 m/s, which is the critical point for future functional decline in community-dwelling older people determined by previous studies.[18 21 22 24 25] These results suggest that walking speed may be the most crucial measurement to determine the demand for personal care in older adults. Measurement of walking speed is reliable, valid, sensitive, inexpensive, safe, quick and a simple tool. Therefore, measurement of walking speed is suitable to use in community settings as a screening tool and evaluation for the effect of a care prevention programme.

Muscle strength and mobility and personal care

In the current study, higher ORs were found for GS and TUG, as well as CWS. Hand GS is an estimate of isometric strength in the upper extremity, but also correlates with strength in other muscle groups,[32] and therefore, is considered an estimate of the overall strength. In addition, GS has proved to be a strong predictor of physical functioning and disability,[33 34] morbidity[35] and mortality.[36 37] Our findings support previous evidence and add cut-points of <26 kg in men and <17 kg in women that discriminate those at high-risk for disability in community-living older people. The TUG has been recommended as a screening tool for identifying older people who are at risk for falling.[38 39] Bischoff *et al*[40] proposed a normative cut-point of 12 s for community-dwelling elderly people between 65 and 85 years of age. In daily clinical practice, elderly persons who perform the TUG in >12 s should receive early evaluation and intervention. Our results regarding TUG cut-points are in line with these previous studies.

Strengths and limitations

Strengths of the present study include a large sample size and we used performance-based assessment, which could determine actual physical capacity and predict subsequent physical disability in community-living older people. However, the present study has a number of limitations. One of the limitations is that we analysed cross-sectional data. Therefore, further investigation of the validity of these tests in predicting the risk of disability in older people using a prospective study design is recommended. Another limitation is that many frail older people using healthcare services cannot walk because they have multiple diseases or geriatric syndromes. Non-ambulatory participants were excluded from our study. Therefore, we acknowledge that the study findings may not be generalised to this frailer group.

CONCLUSIONS

This study provides preliminary evidence that clinical tests of physical performances can predict the risk of disability in older people. Logistic regression analysis selected CWS as the best independent correlate of disability, with good sensitivity and specificity. Further investigation is required, and future research should include a prospective measurement of the risk of disability to more accurately determine the validity of screening tests for this population.

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Acknowledgements We thank the Obu City Office for the help provided with participant recruitment, and staff at the Tsukui Corporation for their assistance with data collection.

Contributors HS designed and organised the study, analysed and interpreted the data, and drafted the manuscript. TS and MS made substantial contributions to the conception, design, analysis and interpretation of the data, and critically revised the draft. All authors took responsibility for the accuracy and integrity of the study. All authors gave the final approval of the version to be published.

Funding This work received financial support from a grant from the Japanese Ministry of Health, Labour and Welfare (Project for optimising long-term care; B-3) and a grant from the National Center for Geriatrics and Gerontology (Research Funding for Longevity Sciences; 22–16). The funding source played no role in the design or conduct of the study; collection, management, analysis or interpretation of the data; or preparation, review or approval of the manuscript.

Competing interests None.

Patient consent Obtained.

Ethics approval Ethics Committee of the National Center for Gerontology and Geriatrics.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

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Performance-based assessments and demand for personal care in older Japanese people: a cross-sectional study

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BMJ Open 2013 3:
doi: 10.1136/bmjopen-2012-002424

Geriatrics Gerontology International   Medline Indexed

Geriatr Gerontol Int 2013; **13:** *458–465*

ORIGINAL ARTICLE: BEHAVIORAL AND SOCIAL SCIENCES

Effects of exercise and tea catechins on muscle mass, strength and walking ability in community-dwelling elderly Japanese sarcopenic women: A randomized controlled trial

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Aim: To investigate the effects of exercise and/or tea catechin supplementation on muscle mass, strength and walking ability in elderly Japanese women with sarcopenia.

Methods: A total of 128 women aged over 75 years were defined as sarcopenic and randomly assigned into four groups: exercise and tea catechin supplementation ($n = 32$), exercise ($n = 32$), tea catechin supplementation ($n = 32$) or health education ($n = 32$). The exercise group attended a 60-min comprehensive training program twice a week and the tea catechin supplementation group ingested 350 mL of a tea beverage fortified with catechin daily for 3 months. Body composition was determined by bioelectrical impedance analysis. Interview data and functional fitness measurements, such as muscle strength, balance and walking ability, were collected at baseline and after the 3-month intervention.

Results: There were significant group × time interactions observed in timed up & go ($P < 0.001$), usual walking speed ($P = 0.007$) and maximum walking speed ($P < 0.001$). The exercise + catechin group showed a significant effect (odds ratio 3.61, 95% confidence interval 1.05–13.66) for changes in the combined variables of leg muscle mass and usual walking speed compared with the health education group.

Conclusions: The combination of exercise and tea catechin supplementation had a beneficial effect on physical function measured by walking ability and muscle mass. **Geriatr Gerontol Int 2013; 13: 458–465.**

Keywords: exercise, muscle mass, physical function, sarcopenic women, tea catechin supplementation.

Introduction

It is generally accepted that aging is associated with a progressive decline of lean body mass, and muscle mass in particular. This involuntary loss of skeletal muscle mass and strength, defined as sarcopenia, has been associated with loss of independence, diminished quality of life, physical disability, increased risk for falls, mobility impairments, high healthcare burden and medical needs, and mortality in the elderly.[1,2] Hence, prevention and treatment of sarcopenia is very important and necessary for the well-being of the growing elderly population. Although there are several methods of treatment that have being researched, skeletal muscle disuse or inactivity has been considered potentially preventable with targeted interventions.[3,4] Resistance exercise is considered the cornerstone of sarcopenia[5] management, as its beneficial effects in increasing muscle mass and strength have been confirmed in previous studies.[6–8]

Furthermore, several studies have investigated the treatment effects of green tea beverages abundant in tea catechins (TC), a chemical anti-oxidant,[9–11] as a potential nutritional supplementation for elderly adults; however, the results are controversial. Previous studies have suggested that TC have many health benefits for different disorders varying from cancer to weight loss.[9,11] Research on TC, and its effects on age-related declines in functional fitness and muscle mass in humans are scarce, and the mice studies available show inconsistent evidence. One study investigated the combined effects of exercise and TC ingestion in mice, and found that concomitant TC ingestion with habitual exercise is beneficial for suppressing age-related declines in physical

Accepted for publication 2 July 2012.

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 doi: 10.1111/j.1447-0594.2012.00923.x

performance,[10] focusing on endurance exercise. Nevertheless, there are few, if any, randomized controlled trials on the effects of exercise and TC supplementation on basic physical function in elderly people.

The purpose of the present study was to investigate the effects of exercise and/or TC ingestion on muscle mass, strength and walking ability in sarcopenic women.

Methods

Study population

Invitation letters were mailed to 1472 people aged 75 years and older who were randomly selected from the Basic Resident Register of elderly people residing in the Itabashi ward of Tokyo, Japan. There were 1355 responses to the invitation letters, where 1094 people agreed to participate and 261 people refused or did not respond. The baseline assessment was carried out at the Tokyo Metropolitan Institute of Gerontology (TMIG) between October and November 2009, where 974 participated and 120 who had initially agreed to participate were absent.

We operationally defined sarcopenic women based on categorization into at least one of the following inclusion criteria: (i) appendicular skeletal muscle mass/height^2 less than 6.42 kg/m^2 and knee extension strength less than 1.01 Nm/kg ($n = 99$);[12,13] (ii) appendicular skeletal muscle mass/height^2 less than 6.42 kg/m^2 and usual walking speed less than 1.10 m/sec ($n = 21$);[14] (iii) body mass index (BMI) less than 22 and knee extension strength less than 1.10 Nm/kg ($n = 130$); and (iv) BMI less than 22 and usual walking speed less than 1.10 m/sec ($n = 16$). Out of 974 people, 266 (27.3 %) participants were operationally defined as sarcopenic (Fig. 1).

Participants for the interventions were recruited from 266 sarcopenic women. Exclusion criteria included: (i) severe knee or back pain; (ii) severely impaired mobility; (iii) impaired cognition (Mini-Mental State Examination [MMSE] score <24);[15] (iv) missing baseline data; and (v) unstable cardiac conditions. A total of 138 participants (51.9%) were excluded from the study based on the exclusion criteria, or declined participation. The present study protocol was approved by the Clinical Research Ethics Committee of TMIG. The intervention procedures were fully explained to all participants and written informed consent was obtained.

Randomized group assignment

After the baseline assessment, computer-generated random numbers were assigned to 128 participants, who were then sorted and equally divided into four groups, and any variable that identified individual information was not included in the randomization process. The groups were randomly assigned to one of the four interventions: exercise and tea catechin supplementation (Ex + TC; $n = 32$), exercise (Ex; $n = 32$), tea catechin supplementation (TC; $n = 32$) or health education (HE; $n = 32$) groups. The allocation sequence was concealed from the study coordinator, and data collection was carried out by separate physical therapy staff members who were also blind to the allocation of treatments.

Outcome measures

Data were collected at baseline and after the 3-month intervention. Measures included interview surveys, body composition assessments and physical function tests. Measurements of height and weight were used to calculate BMI (kg/m^2).

Interview survey

Each participant was interviewed face-to-face to assess the individual's history of falls, fear of falling, pain, exercise habits, urinary incontinence, frequency of going out, self-rated health and so on.

Body composition assessment

Percent body fat, lean body mass, and total and segmental muscle mass were measured using a multifrequency bioelectrical impedance analysis (BIA) instrument that operated at frequencies of 5, 50, 250 and 550 kHz (Well-Scan 500; Elk, Tokyo, Japan). The participants stood on two metallic electrodes on the scales of the BIA instrument barefoot, holding two metallic grip electrodes placed in the palm of each hand with the fingers wrapped around the handrails. Segmental muscle mass values of each leg, arm and the trunk were measured and added to obtain appendicular skeletal muscle mass and leg muscle mass.

Performance measures

The performance measures included muscular strength (grip strength, knee extension strength), walking ability (usual and maximum walking speed, and timed up & go [TUG]) and balance ability (one leg standing time with eyes open). For the TUG test, time was measured in seconds from the time the participants stood up from a straight-backed chair placed against a wall, walked 3 m toward a cone as quickly and safely as possible, walked around the cone, and sat down on the chair again.[16] Assistive walking devices were allowed in measures of walking speed and TUG only if they expressed concerns about walking without a device, or if the investigators believed there was a danger of falling. Knee extension strength was measured twice, and the higher value

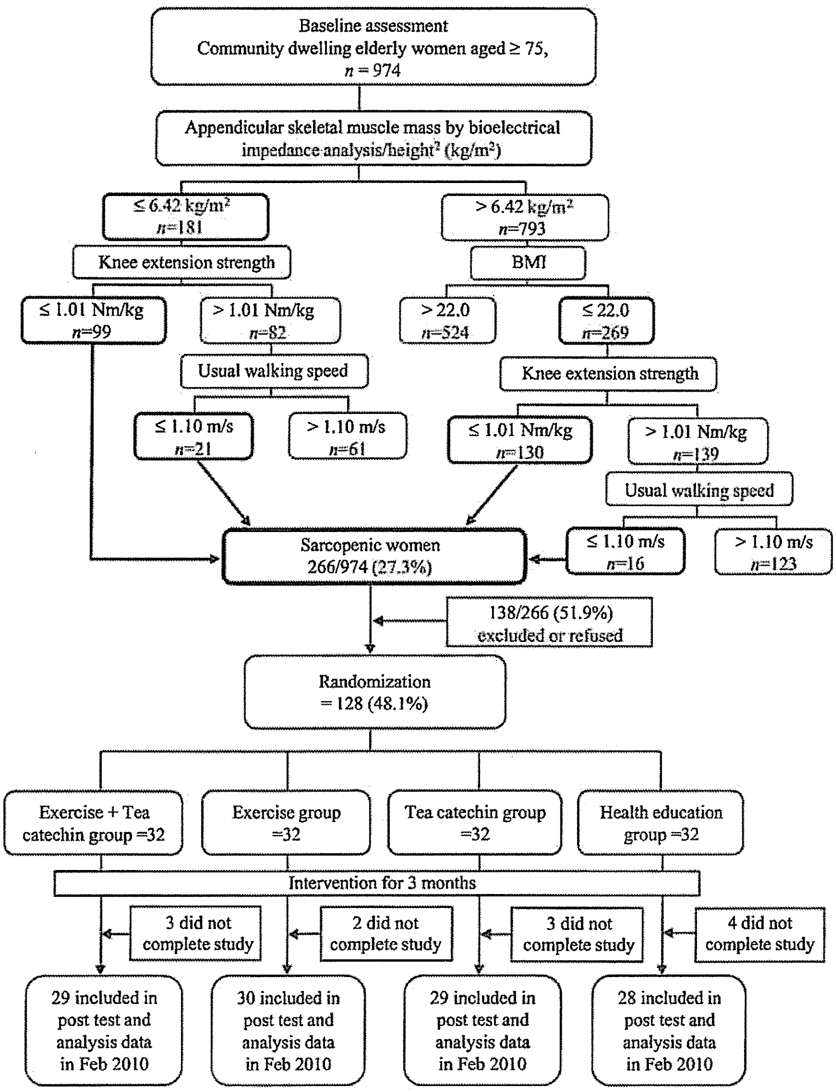

Figure 1 Algorithm for the selection of women operationally defined as sarcopenic, and flowchart of participants in the randomized controlled trial of exercise and tea catechin supplementation. BMI, body mass index.

divided by bodyweight (Nm/kg) was analyzed. Detailed procedures for the performance measures have been described previously.[17]

Intervention

Exercise

The exercise consisted of stretching, muscle strengthening, balance and gait training of moderate intensity maintained at approximately 12–14 on the Borg Rate of Perceived Exertion scale.[18] Each class was 60 min, held at the TMIG twice per week for 3-months. To ensure proper instruction to all participants, the two exercise intervention groups were divided into four subgroups, where the participants exercised together within their assigned subgroup in one of four exercise sessions offered per day.

The exercise session included a 5-min stretching warm-up of the neck, shoulders, lower back, hips, knees and ankles, 30-min of strengthening exercises, 20 min of balance and gait training, followed by a 5-min cool-down.

Muscle strength training

Strengthening exercises were carried out in a progressive sequence from the seated position, which initially provided a secure and stable position, to the standing position. Other resistance was applied through use of resistance bands for upper body strengthening and ankle weights for the lower body, as well as increasing the repetitions and sets of the exercises. Participants were initially instructed to complete up to one eight-repetition set of each type of exercise, which gradually increased to 10 repetitions, and up to two sets.

Resistance was increased on a group basis when the participants were able to execute each exercise without loss of proper execution. Each individual's ability to increase intensity was assessed by the principal investigator, the exercise instructor and assistant trainers.

To strengthen lower extremities, a fixed weight was placed on the ankle during the exercises. Weights of 0.50 kg, 0.75 kg, 1.00 kg, and 1.50 kg were prepared and used in accordance with each participant's strength level as the resistance progressively increased. Strengthening of the leg muscles focused on hip extensors and adductors, knee flexors and extensors, and ankle dorsi- and plantarflexors.

Gait and balance training

The participants practiced various walking patterns, focusing on stability maintenance during walking. Participants were taught to focus their attention on increasing toe elevation of the forward leg, heel elevation of the rear limb, and stride length through gait exercises including walking with directional changes and weight shifting. The balance training contained exercises, such as one-leg stands, tandem stand and tandem walking, for each participant to train their static, dynamic and lateral balancing ability.

Tea catechin supplementation

Bottles containing 350 mL of tea fortified with 540 mg of catechin were provided for the participants in the TC supplementation group every 2 weeks. The participants were instructed to drink one bottle per day, every day for 3 months. To monitor their TC intake accurately, the participants were asked to record the volume of tea consumed (the whole bottle, half the bottle, or about one-quarter) on record sheets that were collected every 2 weeks, along with the bottle caps of finished bottles. Participants who drank at least 54 bottles or more out of the 90 bottles (60%) were considered to have completed the supplementation intervention.

Health education

The HE group served as the control group, and the participants took a class once a month for 3 months, a total of three times. Health professionals taught topics such as cognitive function, the long-term care system and oral hygiene. No specific instructions on diet or physical activity were given, and the participants were asked to continue their regular lifestyle habits.

Data analysis

Differences in baseline measures between the groups were measured using a one-way analysis of variance (ANOVA), and χ^2-tests were carried out on categorical variables. Two-way repeated-measures ANOVA was used to analyze differences in the effect of the intervention on outcome measures between groups, and a post-hoc test was carried out where significant P-values (<0.05) were found to determine which groups were significantly different. Percentage changes in leg muscle mass and strength, and walking ability postintervention were calculated using the formula: % change = ((postintervention value − baseline value) / baseline value) × 100. To compare the effects of the four intervention groups on combined variables of leg muscle mass and functional fitness after 3 months of intervention, multiple logistic regressions were carried out. All analyses were carried out using SPSS software, Windows version 19.0 (SPSS, Tokyo, Japan) and SAS, version 9.2 for Windows (SAS Institute Japan, Tokyo, Japan).

Results

All of the baseline characteristics including age, percent body fat, muscle mass, walking speed, urinary incontinence and falls were similar between the groups (Table 1).

In comparing the pre- and postintervention changes in performance measures and body composition by two-way repeated-measures ANOVA (Table 2), there were significant group × time interactions in TUG ($F = 15.408$, $P = 0.005$), usual walking speed ($F = 4.327$, $P = 0.007$) and maximum walking speed ($F = 15.161$, $P < 0.001$), where the changes in the Ex + TC group were greater than the HE group.

Figure 2 shows the within group analyses of percent changes from pre- to postintervention. Leg muscle mass significantly increased in the Ex + TC group (2.21%, $P = 0.016$), whereas only small changes in the other groups were observed. Usual walking significantly increased in the Ex + TC group (11.36%, $P = 0.010$), a modest increase was seen in the Ex group (4.84%, $P = 0.020$), and slight decreases were observed in the TC and HE groups.

The multiple logistic regression analysis showed that the Ex + TC group had a significant effect on the combined variables of increased leg muscle mass and improved usual walking speed (OR 3.61, 95% CI 1.05–13.66; Table 3). The OR for increased leg muscle mass and knee extension strength in the Ex + TC group, although statistically non-significant, were more than twofold as great as the Ex or TC only groups.

Discussion

Although sarcopenia was originally defined as the age-related loss of muscle mass,[19] muscle strength does not depend solely on muscle mass, and the relationship

Table 1 Selected variable characteristics of participants at baseline by study group

Variables†	Ex + TC (n = 32)	Ex (n = 32)	TC (n = 32)	HE (n = 32)	ANOVA P-value
Age (years)	81.1 ± 3.7	79.6 ± 4.2	80.0 ± 4.0	80.2 ± 5.6	0.525
Height (cm)	145.0 ± 5.5	145.9 ± 5.8	145.6 ± 4.9	145.9 ± 5.4	0.892
Bodyweight (kg)	43.7 ± 4.1	41.5 ± 4.5	42.4 ± 5.7	42.7 ± 5.0	0.413
Percent body fat (%)	29.0 ± 3.7	28.1 ± 4.2	27.8 ± 4.8	30.3 ± 3.6	0.110
Lean body mass (kg)	30.2 ± 3.2	30.4 ± 3.6	29.9 ± 3.1	30.5 ± 2.8	0.894
Muscle mass (kg)	27.8 ± 3.0	28.0 ± 3.3	27.5 ± 2.9	28.1 ± 2.6	0.917
Legs muscle mass (kg)	10.2 ± 1.2	10.2 ± 1.3	10.2 ± 1.2	10.3 ± 1.0	0.992
Grip strength (kg)	18.5 ± 3.5	18.2 ± 4.9	16.1 ± 3.4	17.2 ± 4.0	0.078
Usual walking speed (m/sec)	1.3 ± 0.2	1.2 ± 0.3	1.2 ± 0.2	1.2 ± 0.2	0.677
Maximal walking speed (m/sec)	1.7 ± 0.3	1.6 ± 0.3	1.7 ± 0.3	1.7 ± 0.3	0.235
Timed up & go	6.61 ± 1.63	7.13 ± 1.68	7.07 ± 1.96	6.82 ± 1.21	0.597
One leg standing time with eyes open	27.1 ± 23.5	24.8 ± 21.8	32.1 ± 24.5	34.5 ± 24.4	0.375
Knee extension strength (Nm)	50.4 ± 10.7	44.5 ± 14.8	46.4 ± 9.7	47.0 ± 10.7	0.242
Exercise habit, yes (%)	48.4	40.7	37.5	19.2	0.144
Urinary incontinence, yes (%)	45.2	40.6	40.6	38.5	0.962
Frequency of outings, >once per day (%)	22.6	31.3	34.4	42.3	0.455
Fear of falling, yes (%)	71.0	84.4	68.8	73.1	0.489
Falls, yes (%)	25.8	31.3	21.9	11.5	0.347
Self-rated health, unhealthy (%)	12.9	34.4	25.0	15.4	0.163

†Data are presented as mean and standard deviation for continuous variables, and percentage for categorical variables. ANOVA (one-way analysis of variance) for continuous variables and χ^2-test for categorical variables. Ex, exercise group; HE, health education group; TC, tea catechin group.

between strength and mass is not linear. Recently, the European Working Group on Sarcopenia in Older People recommended using both low muscle mass and muscle strength or low physical performance as indicators for sarcopenia.[20] In the present study, sarcopenic women were operationally defined based on the declines in muscle strength or walking speed that accompany the loss of skeletal muscle mass or low BMI. The results of the present study showed that the combination of exercise and TC can effectively improve muscle mass and walking speed in sarcopenic elderly women; however, the present results could not confirm the efficacy of the combined intervention on both muscle mass and strength.

The benefits of resistance training in increasing muscle mass and strength for older people have been made quite clear throughout the literature.[6–8] According to a recent review, resistance exercise has been shown to increase muscle protein synthesis, and evidence suggests increases in size of both type 1 and type 2 muscle fibers, leading to overall improvement in muscle power and physical functioning.[5] However, our data did not show beneficial effects of exercise alone on measures of muscle mass or strength. This might be because of the intensity the participants in this intervention exercised at, as some studies showed that higher intensity and volume training were associated with greater strength improvements among older populations, compared with low- and moderate-intensity training.[7,21] Nevertheless, high-intensity exercise for frail elderly people is difficult and might lead to negative or adverse outcomes. Exercise at high intensities might aggravate previously mild discomforts of the lower back or knee, potentially causing mild, moderate or even severe pain. Furthermore, motivating frail elderly people to properly carry out high-intensity exercise is very challenging. Even though exercise of high intensity and volume can increase muscle mass and strength effectively, Taaffe[22] has suggested that training once or twice a week at moderate intensity is sufficient for improvement; therefore, the use of such training on frail elderly people should be reconsidered.

The role of anti-oxidants in aging has recently been a topic of interest. Studies have reported that aging skeletal muscle has been associated with decreased oxidative capacity, which might be linked to mitochondrial dysfunction.[23–25] One previous study suggested that TC might prevent decreases in muscle force production in mice.[26] Another mice study indicated that TC can effectively decrease oxidative stress, which might contribute, to a certain extent, to the maintenance of skeletal muscle mitochondrial function and energy metabolism; therefore, the concomitant intake of TC and regular exercise might suppress age-related declines in physical function.[10]

Table 2 Comparison of muscle mass and functional fitness variables among groups after 3-month interventions

Variables†	Group	Baseline	After 3-month intervention	ANOVA (G × T); *P*-value
Muscle mass (kg)	Ex + TC	28.38 ± 2.46	28.33 ± 2.69	*F* = 0.323 *(0.809)*
	Ex	29.09 ± 2.85	28.92 ± 2.98	
	TC	27.47 ± 3.02	27.28 ± 2.83	
	HE	28.23 ± 2.40	28.35 ± 2.33	
Appendicular skeletal muscle mass (kg)	Ex + TC	14.31 ± 1.30	14.18 ± 1.41	*F* = 1.280 *(0.286)*
	Ex	14.79 ± 1.45	14.45 ± 1.57	
	TC	13.66 ± 1.66	13.58 ± 1.51	
	HE	13.96 ± 1.21	14.11 ± 1.23	
Legs muscle mass (kg)	Ex + TC	10.45 ± 0.98	10.57 ± 1.08	*F* = 0.524 *(0.667)*
	Ex	10.59 ± 1.23	10.73 ± 1.22	
	TC	10.14 ± 1.29	10.12 ± 1.14	
	HE	10.30 ± 0.92	10.50 ± 0.94	
Grip strength (kg)	Ex + TC	18.63 ± 3.39	19.33 ± 4.71	*F* = 0.519 *(0.670)*
	Ex	19.11 ± 4.67	19.26 ± 4.54	
	TC	16.41 ± 3.34	17.11 ± 2.81	
	HE	17.84 ± 4.03	17.74 ± 3.59	
Timed up & go (s)	Ex + TC	8.68 ± 1.99	7.37 ± 1.64	*F* = 15.408 *(<0.001)*
	Ex	8.81 ± 1.60	7.03 ± 1.34	
	TC	8.89 ± 2.20	8.44 ± 2.15	
	HE	8.43 ± 1.70	8.88 ± 2.09	
Usual walking speed (m/s)	Ex + TC	1.25 ± 0.21	1.37 ± 0.24	*F* = 4.327 *(0.007)*
	Ex	1.26 ± 0.22	1.36 ± 0.30	
	TC	1.25 ± 0.24	1.24 ± 0.19	
	HE	1.27 ± 0.18	1.26 ± 0.20	
Maximum walking speed (m/s)	Ex + TC	1.74 ± 0.30	2.01 ± 0.39	*F* = 15.161 *(<0.001)*
	Ex	1.73 ± 0.23	2.06 ± 0.32	
	TC	1.78 ± 0.27	1.71 ± 0.23	
	HE	1.79 ± 0.33	1.71 ± 0.30	
Knee extension strength (Nm)	Ex + TC	52.81 ± 9.39	49.85 ± 8.97	*F* = 2.556 *(0.061)*
	Ex	51.39 ± 13.01	49.73 ± 13.38	
	TC	47.34 ± 9.56	39.42 ± 8.29	
	HE	47.54 ± 11.28	43.13 ± 10.93	

†Data are presented as mean and standard deviation. A post-hoc analysis was carried out using the Scheffe method. ANOVA two-way repeated-measure analysis of variance. Ex, exercise group; G, group; HE, health education group; T, time; TC, tea catechin.

Table 3 Adjusted odds ratio for changes in leg muscle mass and functional fitness after intervention according to study group

Dependent variable†	Type of intervention						
	HE	TC		Ex		Ex + TC	
	Reference	OR	95% CI	OR	95% CI	OR	95% CI
Leg muscle mass and usual walking speed	1.00	1.32	0.40–4.70	1.99	0.57–7.38	3.61	1.05–13.66
Leg muscle mass and knee extension strength	1.00	0.40	0.07–2.08	0.82	0.16–4.06	2.25	0.58–9.93

†Dependent variable; change of muscle mass and functional fitness: 1 = improve, 0 = no change or decrease. Ex, exercise; HE, health education; OR, adjusted odd ratio; TC, tea catechin.

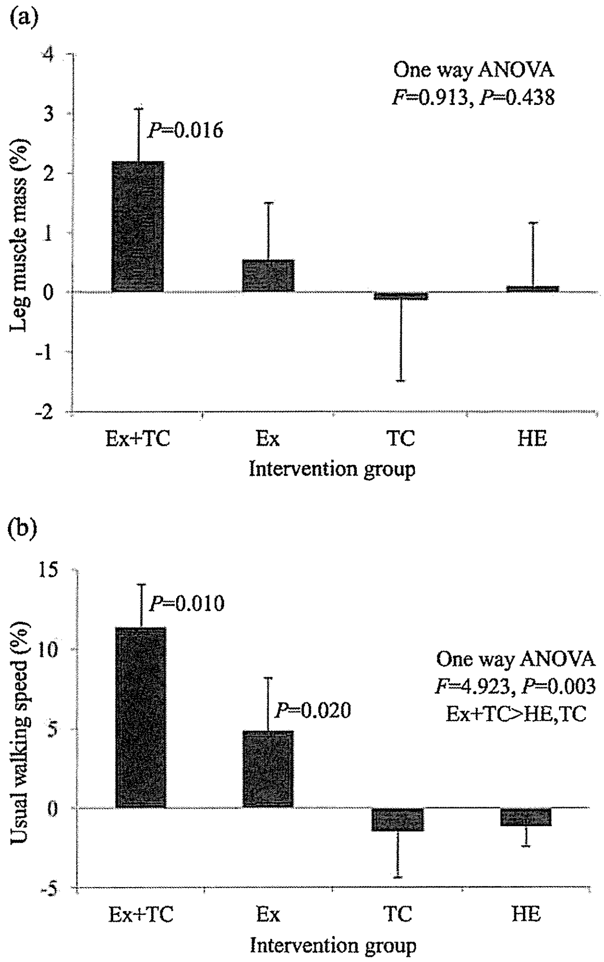

Figure 2 Mean (± SE) changes in (a) leg muscle mass and (b) usual walking speed after exercise (Ex), tea catechin supplementation (TC), usual walking speed after exercise and tea catechin supplementation (Ex + TC), or health education (HE). Bars indicate the average changes from baseline to after the 3-month interventions. A post-hoc analysis was carried out using the Scheffe method.

The data in the present study showed leg muscle mass improvements of 2.21% in the combined exercise and TC group, but the changes in muscle strength were not significant. These results are inconsistent with previous research showing strong associations between increases in muscle mass and increases in strength;[4] hence, further research is necessary.

The improvements observed in walking speed is an important finding, as studies have reported that walking speed is an indicator of vitality and a predictor of functional decline,[27] subsequent disability,[28] survival[29] and other adverse outcomes.[30] A recent statement from the Society on Sarcopenia, Cachexia and Wasting Disease stated that an improvement in gait speed of at least 0.1 m/s can be considered clinically significant.[31] The results of the current study showed that walking speed increased in the Ex group by 0.10 m/s and in the Ex + TC group by 0.12 m/s after the 3-month intervention. Exercise alone or combined exercise and TC supplementation might be effective for improving walking ability in sarcopenic women.

As sarcopenia is a multifactorial condition involving age-related declines in muscle mass, strength or function, effective treatments should target improvements in muscle mass and physical function. In the current study, the OR for muscle mass and usual walking speed improvement was more than threefold as great in the Ex + TC group compared with the HE group. Although investigation into mechanisms of the anti-oxidant capacities of TC together with exercise was beyond the scope of the present study, our results show that the combination of exercise and TC effectively enhanced muscle mass and walking ability.

The present study had several limitations. First, investigation into the mechanisms of the anti-oxidative effects of TC was not explored. Future studies should investigate TC effects on reactive oxygen species and oxidative stress markers in order to provide further understanding and insight into the treatment of sarcopenia. Second, muscle mass was measured using BIA. Other methods of measuring muscle mass, such as magnetic resonance imaging (MRI), computerized tomography and dual-energy X-ray absorptiometry, are typically considered more accurate.[32] Previous studies have reported strong correlations between MRI and BIA measurements for muscle mass in older adults.[12,33,34] Hence, the validity of the BIA measurements has little influence on the interpretation of the results in the present study. Third, 51.9% (138 sarcopenic women) were excluded from the present study based on the exclusion criteria or refused participation, and were not included in this intervention trial. Future research should consider the external validity of the populations included in randomized controlled trials, and perhaps shift the focus to community-dwelling older adults often excluded from intervention studies.

Acknowledgments

This research was supported by a Grant-in-Aid for Scientific Research B from the Japanese Society for the Promotion of Science (22300243). The authors have no financial or any other kind of personal conflicts with this trial. The sponsor had no role in the design and conduct of the study; subject recruitment; collection, management, analysis and interpretation of data; or preparation of the manuscript. M S, Y Y and I T are researchers with Kao Corp., and their contributions limited to providing the tea catechin supplementation. E Hosoi assisted in the revision of manuscript.

Disclosure statement

The authors declare no conflict of interest.

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J Bone Miner Metab (2013) 31:556–561
DOI 10.1007/s00774-013-0443-z

ORIGINAL ARTICLE

Prevalence of sarcopenia in Japanese women with osteopenia and osteoporosis

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Received: 29 September 2012 / Accepted: 14 February 2013 / Published online: 21 March 2013

Abstract Sarcopenia and osteoporosis are both significant health burdens among postmenopausal women. This study examined associations between sarcopenia and osteopenia/osteoporosis in Japanese women and evaluated the prevalence of sarcopenia in women with osteopenia and osteoporosis. A total of 2400 Japanese women aged 40–88 years underwent dual-energy x-ray absorptiometry (DXA) scans of the whole body, lumbar spine, and total hip. Osteopenia and osteoporosis were defined according to World Health Organization criteria using bone mineral density (BMD) of the lumbar spine or hip. Sarcopenia was defined as a relative skeletal muscle index (RSMI) more than 2 standard deviations below the mean for a young adult reference population, calculated as the appendicular skeletal muscle mass (ASM) obtained from whole-body DXA divided by height in meters squared (RSMI = ASM/height^2). Significant and marginal/moderate positive correlations were observed between RSMI and lumbar spine/total hip BMDs ($r = 0.197$ and $r = 0.274$, respectively; $p < 0.0001$ each). The BMDs of the lumbar spine and total hip showed significant moderate negative correlations with age ($r = -0.270$ and $r = -0.375$, respectively; $p < 0.0001$ each), but RSMI showed no association with age in this population ($r = 0.056$). When osteopenia/osteoporosis was defined using lumbar spine BMD, prevalences of sarcopenia in subjects with normal BMD, osteopenia and osteoporosis were 10.4, 16.8, and 20.4 %, respectively. When osteopenia/osteoporosis was defined using total hip BMD, the prevalences of sarcopenia in these subjects were 9.0, 17.8, and 29.7 %, respectively. A Chi-square test for independence showed a significant association between sarcopenia and osteopenia/osteoporosis ($p < 0.0001$). These results indicate that sarcopenia is significantly associated with osteopenia and osteoporosis in Japanese women.

Keywords Sarcopenia · Osteopenia · Osteoporosis · Dual-energy X-ray absorptiometry · Muscle mass

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Introduction

Osteoporosis is a worldwide health problem that is age-related and three times more common in women than in men [1]. The loss of bone mass is a potent risk factor for fragility fractures, and osteoporosis-induced fractures represent a major burden on society [1]. Lifetime risk for hip, vertebral and forearm (wrist) fractures has been estimated as approximately 40 %, similar to that for coronary heart disease [1].

Sarcopenia is defined as the age-associated loss of skeletal muscle mass and function [2]. Sarcopenia is very common in older individuals, with a reported prevalence in 60- to 70-year-olds of 5–13 %, and a prevalence in >80-year-olds of 11–50 % [3]. Sarcopenia increases the risk of falls [4, 5], which enhance fragility fractures including osteoporotic hip fractures. The risk of falls appears more closely related to risk of limb fracture than bone mineral density (BMD) [6]. Concomitant sarcopenia and osteopenia/osteoporosis thus represents a greater risk than osteopenia/osteoporosis alone for limb fractures.

Several factors that play important roles in causing sarcopenia also contribute to bone loss, such as age-related