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Walking speed and balance both improved in older Japanese adults between 1998 and 2018

Tetsuhiro Kidokoro [a], Samantha J. Peterson [b], Hannah K. Reimer [c], Grant R. Tomkinson [c, d, *]

[a] Faculty of Sport Science, Nippon Sport Science University 7-1-1, Fukasawa, Setagaya, 158-8508, Tokyo, Japan
[b] Department of Medical Laboratory Science, University of North Dakota, Grand Forks, ND, USA
[c] Department of Education, Health and Behavior Studies, University of North Dakota, Grand Forks, ND, USA
[d] Alliance for Research in Exercise, Nutrition and Activity (ARENA), School of Health Sciences, University of South Australia, Adelaide, SA, Australia

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Background/objective: Physical function, the ability of an individual to carry out physical tasks, is meaningfully related to health among older adults. Few studies have analyzed temporal trends in objective performance measures of physical function for older adults. The aim of this study was to estimate temporal trends in balance and walking speed for older Japanese adults (aged 65–79 years) between 1998 and 2018.
Methods: Annual, cross-sectional, national fitness surveillance data for balance (n = 114,785) and walking speed (n = 112,289) were reported descriptively by the Japanese Ministry of Education, Culture, Sports, Science and Technology across the 1998–2018 period. Trends in means were estimated by sample-weighted regression, with trends in variability estimated as the ratio of coefficients of variation.
Results: There was a moderate improvement in both mean balance (standardized effect size (ES) change (95% confidence interval (CI)): 0.50 (0.48–0.52)) and mean walking speed (ES change (95%CI): 0.53 (0.51–0.55)). Improvements were seen in all gender and age groups, with small gender-related and negligible age-related temporal differences. Variability declined substantially for both balance (ratio of CVs (95%CI): 0.77 (0.75–0.79)) and walking speed (ratio of CVs (95%CI): 0.87 (0.85–0.89)).
Conclusion: Improved physical performance is suggestive of a corresponding improvement in health. Declines in variability indicate that temporal improvements were not uniform across the distribution.

Introduction

Physical function reflects the ability of an individual to carry out physical tasks,[1] which can be assessed by self-report measures (where an individual reports his/her perceived ability to perform a task) or by physical performance measures (where an individual's ability to physically perform a task is objectively measured). While self-report measures of physical function are common, and are moderately related to physical performance,[2,3] objective performance measures have become increasingly popular as a means of assessing specific aspects of function. Two such physical performance measures—short-distance walking speed and standing balance—are acceptable, feasible, ecologically valid, widely used, and scalable measures of functional speed and balance that have utility for clinical screening and population surveillance[4–6]; and both are considered to be important indicators of health.[7–11] In older adults for example, slow walking speed is significantly associated with all-cause mortality and cardiovascular disease (independent of age, gender, pre-existing medical conditions, and other confounders)[7,11] and a range of adverse health outcomes (e.g., disability, cognitive impairment, institutionalization, falls risk).[7,8] Poor standing balance is associated with increased fracture, hospitalization, and falls risk,[8,10] as well as disability in activities of daily living.[9]

Temporal trends in physical function for older adults have typically examined self-reported ability to perform activities (or

* Corresponding author. Department of Education, Health and Behavior Studies, University of North Dakota, 2751 2nd Avenue North, Stop 8235, Grand Forks, ND, 58202, USA.
E-mail address: grant.tomkinson@und.edu (G.R. Tomkinson).

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Table 1
Temporal trends in means and coefficients of variation for balance and walking speed among 65- to 79-year-old Japanese adults between 1998 and 2018.

Group	n	mean ± SD	Change in means (95%CI)			Ratio of CVs (95%CI)
			Absolute	Percent	Standardized ES	
Balance						
All						
65- to 79-year-olds	114,785	65 ± 44	20.8 (20.0–21.6)	32.5 (31.2–33.8)	0.50 (0.48–0.52)	0.77 (0.75–0.79)
Gender						
Men	57,471	67 ± 43	15.7 (14.6–16.8)	23.0 (21.2–24.8)	0.37 (0.34–0.40)	0.82 (0.79–0.85)
Women	57,314	63 ± 44	24.9 (23.8–26.0)	40.0 (38.1–41.9)	0.59 (0.56–0.62)	0.71 (0.69–0.74)
Age						
65- to 69-year-olds	38,967	80 ± 42	19.6 (18.3–21.0)	24.5 (22.8–26.2)	0.46 (0.43–0.49)	0.72 (0.69–0.75)
70- to 74-year-olds	38,824	66 ± 43	22.4 (21.0–23.8)	34.5 (32.4–36.6)	0.52 (0.49–0.55)	0.75 (0.71–0.78)
75- to 79-year-olds	36,994	49 ± 40	20.6 (19.2–22.0)	43.2 (40.4–46.0)	0.52 (0.49–0.55)	0.80 (0.76–0.84)
Walking speed						
All						
65- to 79-year-olds	112,289	1.4 ± 0.3	0.15 (0.14–0.16)	10.9 (10.4–11.4)	0.53 (0.51–0.55)	0.87 (0.85–0.89)
Gender						
Men	56,311	1.5 ± 0.3	0.13 (0.12–0.14)	8.5 (7.8–9.2)	0.40 (0.37–0.43)	0.96 (0.93–0.99)
Women	55,978	1.3 ± 0.3	0.17 (0.16–0.18)	12.8 (12.1–13.5)	0.64 (0.61–0.67)	0.79 (0.76–0.82)
Age						
65- to 69-year-olds	38,214	1.5 ± 0.3	0.13 (0.12–0.14)	9.1 (8.2–10.0)	0.46 (0.42–0.50)	0.88 (0.84–0.92)
70- to 74-year-olds	38,026	1.4 ± 0.3	0.16 (0.15–0.17)	11.8 (11.0–12.6)	0.57 (0.53–0.61)	0.84 (0.80–0.88)
75- to 79-year-olds	36,049	1.3 ± 0.3	0.16 (0.15–0.17)	12.7 (11.9–13.5)	0.60 (0.56–0.64)	0.89 (0.85–0.93)

Notes: Means±SDs and absolute changes are in seconds (balance) and meters per second (walking speed). Positive changes in means indicated temporal improvements and negative changes indicated temporal declines; standardized ES changes in means of 0.2, 0.5, and 0.8 were used as thresholds for small, moderate, and large, respectively, with ES < 0.2 considered to be negligible; ratio of CVs >1.1 indicated substantial temporal increases in variability and ratios <0.9 indicated substantial temporal declines.
Abbreviations: SD = standard deviation; 95%CI = 95% confidence interval; CV = coefficient of variation; ES = effect size.

instrumental activities) of daily living.[12–17] Unfortunately, these studies may suffer from temporal trends in recall or response bias.[18] While much less is known about temporal trends in objectively measured physical performance, we recently reported improvements in functional endurance (i.e., 6-min walking distance) and strength (i.e., handgrip strength) in a national sample of Japanese adults aged 65–79 years between 1998 and 2017,[19,20] and it is not clear whether similar trends exist for other physical abilities (e.g., balance or walking speed). Available evidence indicates that temporal trends among physical abilities are mixed (i.e., do not correspond) within older adult populations.[21–23] Examination of trends across multiple physical abilities provides insight for interventions, by helping to identify the physical abilities among older adults in greatest need of attention (e.g., if declining). This is important because declines in physical performance may precede physical disability (i.e., the inability to perform activities of daily living).[5] Furthermore, while previous studies have reported trends in mean performance[21,22] or point prevalence of impairment,[23] it is unknown whether temporal trends in distributional characteristics (i.e., trends in distributional variability and/or asymmetry) have concurrently occurred. Such knowledge would help to identify whether the trends in physical performance were uniform or nonuniform across the distribution.

The Japanese Ministry of Education, Culture, Sports, Science and Technology[6] has conducted annual national fitness surveillance of 65-to 79-year-olds since 1998, including objectively measured standing balance and short-distance walking performance, and has published the results annually as summary statistics. Using these national data, the aim of this study was to estimate temporal trends (in means and variability) in balance and walking speed for older Japanese adults (aged 65–79 years) between 1998 and 2018. Trends in these physical abilities improves our understanding of trends in population health, facilitates comparisons between physical abilities within populations and within physical abilities between populations, guides interventions, and helps assess the impact of public health policy.

Materials and methods

Participants and sampling procedures

Since 1998, annual, cross-sectional, national fitness surveillance of older Japanese adults (aged 65–79 years) has been performed by the Ministry of Education, Culture, Sports, Science and Technology. While this national surveillance system is described in detail elsewhere,[24] briefly, national samples of older adults have had their physical performance tested annually between May and October, with results statistically processed and published as summary statistics (sample sizes, means, and standard deviations (SDs)).[6] Older adults were recruited from all 47 prefectures of Japan by local education boards, which tried to recruit representative samples by recruiting residents from geographically diverse areas (both urban and rural areas) within each prefecture, with target sample sizes of $n = 20$ per gender-age-prefecture group. Summary statistics were available for six gender-age groups (men and women aged 65–69 years, 70–74 years and 75–79 years). All summary statistics are publicly available and have been published annually by the Ministry of Education, Culture, Sports, Science and Technology,[6] and because only summary statistics were used in our analysis, our study was exempted from review by the university institutional review board at the authors' respective universities and from subject informed consent.

Prior to exercise, participants underwent a health exam administered by a doctor or a nurse and completed an activities-of-daily-living questionnaire.[25] Participants were excluded from participation in the balance and walking tests for safety reasons if they were unable to stand unsupported on one leg. Unfortunately, no data on medical exclusions were available.

Testing procedures

Functional balance and speed were measured by trained technicians using standardized testing protocols and equipment.[25] Balance was measured in bare feet by a single-leg standing balance test, where participants stood for as long as possible on their preferred leg (in an extended position), with their eyes open and their hands on hips. The test ended when participants (a) used their raised foot by touching the floor or the weight-bearing leg, (b) moved their weight-bearing foot to maintain balance, or (c) separated either hand from their hips. The time in standing was measured by a stopwatch to the nearest 1 s, up to a maximum of 120 s, with the better of two trials recorded. A 10 m obstacle walking test was also measured, which required participants to walk as fast as possible (in shoes, and safely without running) along a non-slip course while stepping over six obstacles (0.2 m high, 0.1 m deep and 1 m wide) spaced 2 m apart from start to finish. The time taken was measured by a stopwatch to the nearest 0.1 s, with the better of two trials recorded. We then calculated mean walking speed (m/s) by dividing the total distance (10 m) by the mean time taken (s).

Statistical analyses

Temporal trends in means were estimated from summary statistics for each gender-age group using sample-weighted linear regression.[26,27] Trends in means were expressed as absolute changes (i.e., the regression coefficient), percent changes (i.e., the regression coefficient expressed as a percentage of the sample-weighted mean), and as standardized (Cohen's) ES (i.e., the regression coefficient divided by the pooled SD). To interpret the magnitude of the changes in means, ES of 0.2, 0.5, and 0.8 were used as thresholds for small, moderate, and large, respectively, with ES < 0.2 considered to be negligible.[28] Positive changes indicated temporal improvements and negative changes indicated temporal declines.

Using procedures described elsehwere,[27] we calculated population-weighted mean changes (for men, women, 65-to 69-year-olds, 70-to 74-year-olds, 75-to 79-year-olds, and all older adults (65-to 79-year-olds)) by pooling the changes across all relevant gender-age groups using a post-stratification procedure.[29] Population weights were obtained from gender-age-specific population estimates for Japan in 2000 using United Nations[30] data. This post-stratification population-weighting procedure corrected for sampling bias and standardized the changes to underlying population demographics.

Trends in coefficients of variation (CV, the ratio of the SD to the mean) were estimated from summary statistics as the ratio of CVs between 2018 and 1998 using the procedure described elsewhere.[19,20] Ratios >1.1 indicated substantial increases in distributional variability (i.e., the magnitude of variability in relation to the mean increased over time), ratios <0.9 indicated substantial declines in variability (i.e., the magnitude of variability in relation to the mean decreased over time), and ratios between 0.9 and 1.1 inclusive indicated negligible trends in variability (i.e., the magnitude of variability in relation to the mean did not change substantially over time).[31]

Results

Trends in balance

Collectively, there was a moderate improvement in mean balance (change (95% confidence interval (CI)): 20.8 s (20.0–21.6), 32.5% (31.2–33.8), or 0.50 ES (0.48–0.52)) between 1998 and 2018 (Table 1). There was a small gender-related temporal difference, with a moderate improvement for women (change (95%CI): 0.59 ES (0.56–0.62)), and a small improvement for men (change (95%CI): 0.37 ES (0.34–0.40)). In contrast, the age-related temporal differences were negligible.

Distributional variability in balance declined substantially over the 20-year period (ratio of CVs (95% CI): 0.77 (0.75–0.79)). There were substantial declines in variability for all gender and age groups, with the decline 1.6-fold larger for women compared to men, and 1.1- and 1.4-fold larger for 65-to 69-year-olds compared to 70-to 74-year-olds and 75-to 79-year-olds, respectively.

Trends in walking speed

There was a moderate improvement in mean walking speed (change (95%CI): 0.15 m/s (0.14–0.16), 10.9% (10.4–11.4), or 0.53 ES (0.51–0.55)) over the 20-year period. There was a small gender-related temporal difference (change (95%CI): men, 0.40 ES (0.37–0.43); women, 0.64 ES (0.61–0.67)), with negligible age-related temporal differences.

Distributional variability in walking speed declined substantially post-1998 (ratio of CVs (95% CI): 0.87 (0.85–0.89)). Variability declined substantially for (a) women but not men (ratio of CVs: 5.3-fold larger for women), and (b) all age groups, with similar magnitudes of decline.

Discussion

This study estimated temporal trends in functional balance and speed using a national sample of older Japanese adults between 1998 and 2018. The principal findings were (a) there were moderate improvements in balance and walking speed, which were equivalent to 75-to 79-year-olds' mean balance and walking speed improving to better than that seen for 70-to 74-year-olds in 1998 (i.e., when 5 years younger); (b) balance and walking speed improved in all gender and age groups, with small gender-related and negligible age-related temporal differences; and (c) variability in both balance and walking speed declined substantially across all gender and age groups, except for walking speed in men. Our present finding of improved functional balance and speed, complemented by our previous findings of improved functional endurance[19] and strength,[20] collectively indicate that the overall physical function of older Japanese adults is better today than at the turn of the century. This may be meaningful to public health given that poor physical function is an important risk factor for a range of adverse health outcomes,[7–11] and evidence of corresponding improvements in healthy life expectancy among older Japanese adults.[32,33] This is especially important given that Japan's population is aging and has the highest proportion of older adults in the world.[34]

Explanation of main findings

Trends in physical performance are likely due to trends in a network of physiological, physical, behavioral, social, and/or environmental factors.[26] We have previously reported temporal increases in body size (operationalized as height and body mass),[19] muscular strength (operationalized as handgrip strength),[20] and leisure-time physical activity levels (operationalized as self-reported exercise/sport participation)[19] for older Japanese adults between 1998 and 2017. Perhaps recent increases in these factors help to explain our finding of improved balance and walking speed among older Japanese adults. Increased height probably reflects increased leg and stride lengths resulting in improved walking speed,[35,36] although the impact on balance was likely negligible.[37] Increased handgrip strength may reflect a corresponding increase in leg and postural strength,[38] which in turn have contributed to improved balance[39] and walking speed.[40,41] Trends in physical performance are probably also affected by behavioral changes such as increased exercise/sport participation.[19,36] In Japan, national physical activity guidelines recommended that older adults accumulate at least 40 min of aerobic exercise at any intensity every day.[42] While this temporal connection is potentially circumstantial, it does at least suggest that Japan's national promotion of physical activity might be a suitable population approach to improving physical performance in older adults.

Our finding of a gender-related temporal difference for both balance and walking speed indicated that the gender gap in these physical abilities has recently diminished, which might be due to a gender-related temporal difference in physical activity levels. We previously found a somewhat larger increase in the percentage of older Japanese adults who participated in exercise/sport at least 3 days per week for women compared to men.[19] It is not exactly clear whether there has been a corresponding difference in occupational, household, or transport physical activity levels, which are major contributors to total physical activity levels. Nevertheless, perhaps the recent promotion of gender equality policies and programs in Japan has helped to reduce the gender gap in physical performance through increased opportunities for women to be physically active during their free time.[43,44] Gender-related temporal differences in body size and/or motivation levels may also be involved.

We also found substantial declines in distributional variability for both balance and walking speed, which indicated that the improvement in mean performance was not uniform across the population. Unfortunately, without evidence of concurrent trends in distributional asymmetry (e.g., skewness), we were unable to determine whether the decline in variability was due to the low tail, high tail, or both tails, moving towards the middle.

Comparisons with other studies

Few studies have reported temporal trends across multiple physical abilities for older adults.[21–23] Firstly, examination of these studies indicates temporal differences among physical abilities within populations. In contrast, our current finding of improved functional balance and walking speed, coupled with our previous findings indicating improved functional endurance[19] and strength[20] suggest that, at least among older Japanese adults, there has been an overall improvement in physical performance. This is not surprising given the significant positive relationships between balance, muscular strength, and walking speed.[41]

Secondly, further examination across studies indicates a temporal correspondence between populations for walking speed but a temporal difference for balance. For example, improvements in walking speed were also observed by Christensen et al.[21] and Henchoz et al.,[22] with Santoni et al.[23] finding reduced functional impairment in walking speed. On the other hand, our trends for balance differed to those of Henchoz et al.[22] and Santoni et al.[23] who found no change in mean balance and point prevalence of impairment in balance, respectively. Such differences may be real or may reflect differences in populations, sampling, medical screening, or testing protocols.

Strengths and limitations

This study adds to a small body of literature on temporal trends in objectively measured physical performance among older adults. Using national fitness data from repeated annual cross-sectional samples that were collected at the same time of year using a consistent sampling strategy, we estimated trends in means and distributional variability in two acceptable, feasible, and scalable performance measures of physical function, which have excellent test-retest reliability[4–6] and health-related predictive validity.[7–11] In addition, our stratified analysis enabled us to assess and control for potential confounders (e.g., age, gender).

Despite these strengths, some limitations existed. Firstly, while the use of summary statistics did not bias our trend estimates, it did mean we were unable to (a) statistically account for trends in some potential confounders (e.g., body size, physical activity levels, socioeconomic status), (b) assess trends in distributional asymmetry, and (c) assess the potential influence of our trends on health outcomes. Secondly, the use of summary statistics based on repeated cross-sectional samples rather than mixed longitudinal samples meant we were unable to examine period and cohort effects. Thirdly, the use of pre-exercise screening criteria to ensure participant safety could have biased our trends estimates if less fit/less healthy and/or physically impaired older adults were excluded or opted out. Although the generalizability of our findings to the entire 65-to 79-year-old Japanese population is therefore reduced, it is challenging to estimate the magnitude of bias without any temporal data on medical exclusions or overall non-response rates. However, it is unlikely our trends were biased given two proxies indicated (a) no significant temporal differences in samples sizes between measures of body size and physical performance, and (b) no significant temporal trends in the proportion of participants who self-reported as apparently healthy or physically fit.[19]

Conclusions

There has been a moderate improvement in mean balance and walking speed among older Japanese adults since 1998, which is suggestive of corresponding improvements in health. We found negligible age-related temporal differences, yet small gender-related temporal differences, which indicated a closing of the gender gap. Additionally, we found a substantial decline in distributional variability, which indicated that temporal improvement was not uniform across the population. Japan's unique and historical annual national surveillance of physical performance among older adults provides insight into corresponding trends in population health, potentially predicts future disease burden, and highlights the potential opportunity for other countries to engage in a cost-effective public health surveillance strategy.

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Data statement

The datasets analyzed in this study are available from the Ministry of Education, Culture, Sports, Science and Technology[6] and the corresponding author upon reasonable request.

Authors' contributions

TK developed the research question, designed the study, had full access to the data, takes responsibility for the integrity of the data, and drafted the manuscript. SJP had full access to the data, assisted with the statistical analysis, contributed to the interpretation of results, and critically reviewed the manuscript for important intellectual content. HKR had full access to the data, assisted with the statistical analysis, contributed to the interpretation of results, and critically reviewed the manuscript for important intellectual content. GRT developed the research question, designed the study, had full access to the data, takes responsibility for the integrity of the data, led the statistical analysis, and drafted the manuscript. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

Declaration of competing interest

The author(s) have no conflicts of interest relevant to this article.

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