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Title

Temporal trends in handgrip strength for older Japanese adults between 1998 and 2017

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Running title

Trends in handgrip strength for older Japanese adults

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Data availability statement

The datasets analysed in this review are available from the corresponding author on reasonable request.

Compliance with Ethical Standards

All authors declare no conflicts of interest and received no financial support for this project.

Contributions

GRT, TK and TD developed the research question, designed the study, had full access to the data, and take responsibility for the integrity of the data. GRT and TD led the statistical analysis and synthesis of results. GRT and TK led the writing of the manuscript. All authors contributed to the interpretation of results, editing and critical reviewing of the final manuscript, and approved the final manuscript.

Abstract

Objective: To estimate temporal trends in handgrip strength (HGS) for older Japanese adults between 1998 and 2017.

Design and Methods: Adults aged 60–79 years were included. Annual nationally representative HGS data (n=176,449) for the 19-year study period were obtained from the Japanese Ministry of Education, Culture, Sports, Science and Technology. Temporal trends in mean HGS were estimated by sample-weighted regression models relating the year of testing to mean HGS. National trends in absolute, percent and standardized HGS were estimated by a post-stratified population-weighting procedure. Temporal trends in variability were estimated as the ratio of coefficients of variation (CVs).

Results: Collectively, there was a small improvement in mean HGS of 1.4 kg (95%CI: 1.3–1.5), 4.5% (95%CI: 4.3–4.7), or 0.27 standard deviations (95%CI: 0.26–0.28) between 1998 and 2017. The rate of improvement progressively increased over time, with more recent values (post-2008) 1.5-fold larger than earlier values. Gender- and age-related temporal differences were negligible. Variability in HGS declined substantially over time (ratio of CVs [95%CI]: 0.88 [0.86–0.90]), with declines 1.9-fold larger in women compared to men, and 1.7-fold larger in 70–79-year-olds compared to 60–69-year-olds.

Conclusions: There has been a small, progressive improvement in mean HGS for older Japanese adults since 1998, which is suggestive of a corresponding improvement in overall strength capacity. The substantial decline in variability indicates that the improvement in mean HGS was not uniform across the population.

Introduction

Muscular strength reflects the ability of a muscle or muscle group to generate force in a single contraction [1]. Strength cannot be defined by a single measurement because tests are often specific to the muscle group, action, contraction, velocity, range of motion, and equipment. However, handgrip strength (HGS) — characterized as a maximal isometric grip force task — is a practical, feasible, ecologically valid, widely used, and scalable measure of strength capacity for clinical and population screening and surveillance [2,3]. In adults, HGS has moderate-to-high construct validity with knee extensor strength [3], very high test-retest reliability [4], and is generally safe [5].

HGS is a powerful marker of current and future health status in older adults [2]. Low HGS is significantly associated with all-cause, cardiovascular, and non-cardiovascular mortality (independent of body size, physical activity levels, and other covariates) [6], cancer [7], stroke [6], type 2 diabetes [8], hypertension [8], fractures [9], depression [10], cognitive declines [9], and functional limitations [11]. Evidence from the Prospective Urban-Rural Epidemiology (PURE) study [6], which followed-up 139,691 adults (35–70 years) from 17 countries over a median of four years, indicated that every 5-kilogram (kg) decrease in HGS was associated with 16–17% higher hazard ratios for all-cause, cardiovascular, and non-cardiovascular mortality. This health-related evidence supports the recent promotion of muscle-strengthening activities (in addition to aerobic activities) in global physical activity guidelines for older adults [12]. For these reasons, temporal trends in HGS may provide important insights into corresponding trends in population health.

Temporal trends in physical fitness have largely focused on cardiorespiratory fitness [13], with much less known about temporal trends in muscular strength. Several studies have recently reported on temporal trends in HGS for older adults [14–16]. For example, Shields et al. [14] revealed a decline in mean HGS of 1.1 kg, or 1.3–2.2%, per decade from 1981 to 2007–09 for Canadian adults aged 60–69 years. Similarly, Dodds et al. [15] reported a decline in mean HGS of 1.4–3.0 kg, 6.1–8.5%, or 0.3 standard deviations, per decade between 2004 and 2013 for 11,476 English adults aged 50–89 years. In another study examining temporal trends in mean HGS for 35,453 Europeans (aged 50–90+ years) between 2004–05 and 2013, Ahrenfeldt et al. [16] reported improvements (per decade) in Northern Europe (Denmark and Sweden) of 1.1 kg (3.1%) and in Southern Europe (Italy and Spain) of 1.9 kg (6.1%), and a decline in Central Europe (Belgium, Germany, and The Netherlands) of −0.9 kg (−2.5%). While these studies show mixed trends in mean HGS, two of them [14,16] allowed for the examination of temporal trends in the distribution of HGS across the population. Temporal trends in mean-median differences indicated that trends in HGS were uniform [14] and positively skewed (i.e., towards those with high HGS) [16] across the population, respectively.

Examining temporal trends in HGS among other countries will not only improve insights into population health for such countries, but also will facilitate comparisons between countries and bolster generalizability of findings. This might be of particular importance for comparisons between Western and Asian countries because of lifestyle and body composition differences. The Japanese Ministry of Education, Culture, Sports, Science and Technology has conducted annual national fitness surveillance of 60–79-year-olds since 1998, and published descriptive data in their annual "Report Book on the Survey of Physical Fitness and Athletic Ability" [17]. Using data from these surveys, we estimated temporal trends (in means and variability) in HGS for older Japanese adults (aged 60–79 years) between 1998 and 2017.

Methods

Annual national fitness surveillance of Japanese people (aged 6–59 years) has been performed by the Ministry of Education, Culture, Sports, Science and Technology since 1964 [18]. In 1998, the national fitness surveillance system was revised to include new fitness constructs, test measures, and a wider age demographic (6–79 years). The national fitness surveillance system, which involves annual cross-sectional sampling of the Japanese population, is described in detail elsewhere [18]. Annual fitness testing of older adults was conducted between May and October, with results statistically processed and reported descriptively (e.g., sample sizes, means, and standard deviations) each year from 1998 onwards [17]. Older adults were recruited from all parts of Japan (i.e., all 47 prefectures), with descriptive fitness data available for eight gender-age groups (men and women aged 60–64 years, 65–69 years, 70–74 years, and 75–79 years). Local Education Boards 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 (65–79 years) and n=40 (60–64 years) per gender-age-prefecture group. In total, HGS data were available for 176,449 older adults (60–79 years) between 1998 and 2017, with a median sample size of 18,586 (range: 17,578 to 35,214) per gender-age group.

Prior to performing the HGS test, participants underwent a health exam administered by a doctor or a nurse, and completed an activities of daily living questionnaire, with participants excluded if the doctor or nurse felt that the HGS test was contraindicated [19]. HGS was measured to the nearest 0.1 kg using a Smedley-type hand dynamometer (Scandidact, Denmark) according to a standardized testing protocol [19]. Before testing, the dynamometer was adjusted for hand size by ensuring that the middle and proximal phalanges were bent to 90° and the middle phalanges rested flat atop of the handle. Participants stood upright, with their arm extended and hanging down, and squeezed the dynamometer with maximal effort. Two trials were completed for each hand, with HGS recorded as the average of the maximum score attained for each hand.

Temporal trends were analyzed from descriptive data in separate gender-age groups using best-fitting sample-weighted linear or polynomial (quadratic or cubic) regression models relating the year of testing to mean HGS [13]. Trends in means were expressed as absolute changes, percent changes (i.e., change in means expressed as a percentage of the overall mean) and as standardized effect sizes (ES) (i.e., change in means divided by the pooled standard deviation). To interpret the magnitude of change, 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 [20]. Positive temporal trends indicated improvements in means and negative temporal trends indicated declines in means.

National temporal trends (for men, women, 60–69-year-olds, 70–79-year-olds, and all [60–79-year-olds]) were calculated using a post-stratified population-weighting procedure that has been described in detail elsewhere [13]. Population estimates were standardized to the year 2000—a common testing year to all gender-age groups—using United Nations data [21]. The post-stratification population-weighting procedure helps correct the trends for sampling bias by standardizing the trends to underlying population demographics.

The variability of measurements about the mean value was quantified as the coefficient of variation (CV; the standard deviation divided by the mean). Trends in variability were analyzed from descriptive data by: (a) fitting sample-weighted linear regression models relating the year of testing to the CVs; (b) predicting the CVs corresponding to the first (i.e., 1998) and last (i.e., 2017) testing years (this eliminated any distortion that may have arisen from atypical CVs in those years); and (c) calculating the ratio of CVs by dividing the 2017 CVs by the 1998 CVs [22]. Ratios >1.1 indicated substantial temporal increases in variability, ratios <0.9 indicated substantial temporal declines in variability, and ratios between 0.9 and 1.1 indicated negligible temporal trends in variability [22].

Results

Overall, there was a small improvement in mean HGS of 1.4 kg (95% Confidence Interval [95%CI]: 1.3–1.5), 4.5% (95%CI: 4.3–4.7), or ES 0.27 (95%CI: 0.26–0.28) (Table 1), with the rate of improvement progressively increasing over time and more recent values (post-2008) 1.5-fold larger than earlier values (Figure 1). Small improvements were also observed for both men and women, with rates of improvement increasing similarly over time for both genders. Small improvements were also observed across age groups, with negligible differences in rates of improvement. The rate of improvement progressively increased over time in both age groups, with recent values 1.3–1.7-fold larger than earlier values.

Table 1 about here

Figure 1 about here

Variability in HGS declined substantially between 1998 and 2017 (ratio of CVs [95%CI]: 0.88 [0.86–0.90]) (Table 1). Variability declined substantially in women but not men (ratio of CVs:

1.9-fold larger in women), and in 70–79-year-olds but not 60–69-year-olds (ratio of CVs: 1.7-fold larger in 70–79-year-olds).

Discussion

This study estimated temporal trends in HGS for 176,449 older Japanese adults aged 60–79 years between 1998 and 2017. The principal findings were that: (a) there was a small improvement in HGS equivalent to 1.4 kg, 4.5%, or 0.27 standard deviations; (b) the rate of improvement progressively increased with rates of increase larger in the most recent decade; (c) HGS improved in all gender and age groups, with negligible gender- and age-related temporal differences; and (d) variability in HGS declined substantially over time, with declines larger in women compared to men, and in 70–79-year-olds compared to 60–69-year-olds. Our findings of improved HGS suggests that strength capacity in today's older Japanese adults is higher than that of their peers from two decades past. Because Japan is an aging society with the highest proportion of older adults in the world [23], improvements in HGS may be meaningful to public health given significant associations between HGS and health-related outcomes [6–11], and evidence of corresponding improvements in healthy life expectancy in older Japanese adults (e.g., declines in disability and mortality rates, and treatment rates of chronic medical conditions) [24].

Because HGS demonstrates moderate-to-high construct validity [3], our finding of improved HGS is suggestive of improved overall strength capacity; specifically however, it reflects an improved ability of older Japanese adults to perform everyday high intensity gripping tasks. Body size and composition positively influence muscular strength [25], and improved absolute HGS probably reflects a corresponding increase in body size. Temporal trends in strength capacity and body size are likely influenced by improved standards of living (e.g., improved health, education and income), healthier lifestyles (e.g., improved nutrition and physical activity levels), and more effective disease prevention and treatment [25], although it is difficult to estimate the effect of such factors on our trends. Temporal data from Japan's national surveillance system [17] indicate increases in height and body of older Japanese adults between 1998 and 2017. An increase in body size probably reflects increases in both fat mass and fat-free muscle mass [26]. Increased fat-free muscle mass should lead to increased HGS given that muscle force is proportional to its physiological cross-sectional area [27].

Physical activity also positively influences muscular strength in older adults [28], suggesting that increased HGS reflected increased physical activity participation. Temporal data from Japan's national surveillance system [17] indicate increases in the proportion of older Japanese adults participating in exercise/sport at least one day per week, three days per week, and 30 minutes per session. The temporal coincidence of increased HGS, body size, and exercise/sport participation does at least suggest that strategies promoting the development of fat-free muscle mass (e.g., resistance exercise training involving the upper body) [28] and physical activity (e.g., Japan's physical activity guidelines) [29] might be suitable population approaches to improving HGS in older adults.

The distribution of HGS values in older Japanese adults has changed since 1998. Our finding of a substantial decline in variability indicates that the improvement in mean HGS was not uniform across the population, either because one or both tails of the distribution have moved towards the middle (median) over time. In comparison, Shields et al. [14] and Ahrenfeldt et al. [16] reported uniform and non-uniform (i.e., positively skewed) trends in HGS across the population, respectively. Unfortunately, without evidence of corresponding trends in measures of asymmetry (e.g., skewness), we were unable to determine whether the left tail (i.e., those with low HGS), right tail (i.e., those with high HGS), or both tails of the distribution changed over time. Future studies should estimate temporal trends in measures of asymmetry when evaluating temporal trends in HGS, especially as health-related criterion-referenced cut-points emerge [30].

While few studies have examined temporal trends in HGS for older adults, in contrast to our findings, recent trends are mixed, indicating a decline in the HGS of older Canadian [14], English [15], and Central European [16] adults, and an improvement in older Northern and Southern European [16] adults. Surprisingly, declines in HGS for older Canadian [14] and English [15] adults have coincided with increases in body size (i.e., body mass index), suggesting that declines in other factors (e.g., habitual physical activity levels) may be involved. However, the recent decline in mean HGS for older English adults was independent of trends in body size and self-reported physical activity levels, as well as other confounders such as socioeconomic position and smoking history [15]. Although trends in body size and physical activity levels were not directly examined in this study, it appears as though the improvement in HGS observed in older Japanese adults has, as expected, corresponded to increases in body size and exercise/sport participation [17].

This study has several strengths. Using nationally representative data collected by trained measurement teams at the same time of year, this was the first study to estimate temporal trends in HGS for older Japanese adults. It estimated trends in means using weighted regression and a post-stratification population weighting procedure. Unfortunately, we could only estimate temporal trends in HGS using descriptive data as opposed to raw data, meaning we were unable to statistically remove the effects of underlying mechanistic factors (e.g., body size, physical activity levels) or to determine whether the trends were symmetric across the population. The use of descriptive data, coupled with the fact that the national fitness surveillance system relied on repeated cross-sectional sampling rather than mixed longitudinal sampling, meant we were unable to examine period and cohort effects. The use of descriptive data reported in 5-year age bands meant we could not rule out the possibility that our trends were affected by aggregation bias related to differences in age distributions within age bands. Furthermore, while HGS estimates could have been biased if weaker individuals were more likely to opt out of, or were medically excluded from, the national surveys, without any evidence of temporal trends in overall non-response or pre-exercise exclusion rates, it is difficult to determine if our trends in HGS were systematically biased.

Conclusion

This study found a small, progressive improvement in mean HGS for older Japanese adults since 1998, with negligible gender- and age-related temporal differences. We also found that variability in HGS declined over time, indicating that temporal trends were not uniform across the population. The decision for Japan to continuously monitor HGS is recognition of the importance of HGS as a marker of population health, and provides a lesson learnt in national fitness surveillance for other countries to follow in order to track trends in population health and fitness, to guide public health and social care planning, and to potentially predict future chronic disease burden.

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Tables

Table 1. Temporal trends in mean and CV HGS for 60–79-year-old Japanese adults between 1998 and 2017.

Group	n	Change in means (95%CI)			Ratio of CVs (95%CI)
		Absolute (kg)	Percent (%)	Standardized (ES)	
All					
60–79-year-olds	176,449	1.4 (1.3–1.5)	4.5 (4.3–4.7)	0.27 (0.26–0.28)	0.88 (0.86–0.90)
Gender					
Men	86,515	1.6 (1.5–1.7)	4.3 (4.1–4.5)	0.28 (0.27–0.29)	0.92 (0.89–0.95)
Women	89,934	1.1 (1.0–1.2)	4.7 (4.4–5.0)	0.27 (0.25–0.29)	0.85 (0.83–0.88)
Age					
60–69-year-olds	103,984	1.1 (1.0–1.2)	3.4 (3.2–3.6)	0.21 (0.20–0.22)	0.91 (0.89–0.94)
70–79-year-olds	72,465	1.7 (1.6–1.8)	6.2 (6.0–6.4)	0.35 (0.34–0.36)	0.85 (0.82–0.88)

Note: positive changes in means indicated temporal improvements in means and negative changes indicated temporal declines in means; standardized changes (ES) 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; n=sample size; CV=coefficient of variation; 95%CI=95% confidence interval; HGS=handgrip strength; all absolute changes in means were represented as changes in kilograms (kg); because of negligible age-related temporal differences, the age-related trends in HGS were summarized here in 10-year age bands rather than in 5-year age bands.

Figure caption

Figure 1. Temporal trends in mean HGS for 60–79-year-old Japanese adults between 1998 and 2017.

Note: HGS=handgrip strength. Temporal trends are shown for all Japanese adults aged 60–79 years as well as different age and gender groups; data are standardized to the year 2000=100%, with values >100% indicating better HGS and values <100% indicating poorer HGS; the solid lines are the Lowess curves (tension=66) which are used to represent the trends in mean HGS, with upward sloping lines indicating improvements over time and downward sloping lines indicating declines over time; mean (95%CI) percent changes (per decade) are shown at the top of each panel; because of negligible age-related temporal differences, the age-related trends in HGS were summarised here in 10-year age bands rather than in 5-year age bands.

Figures

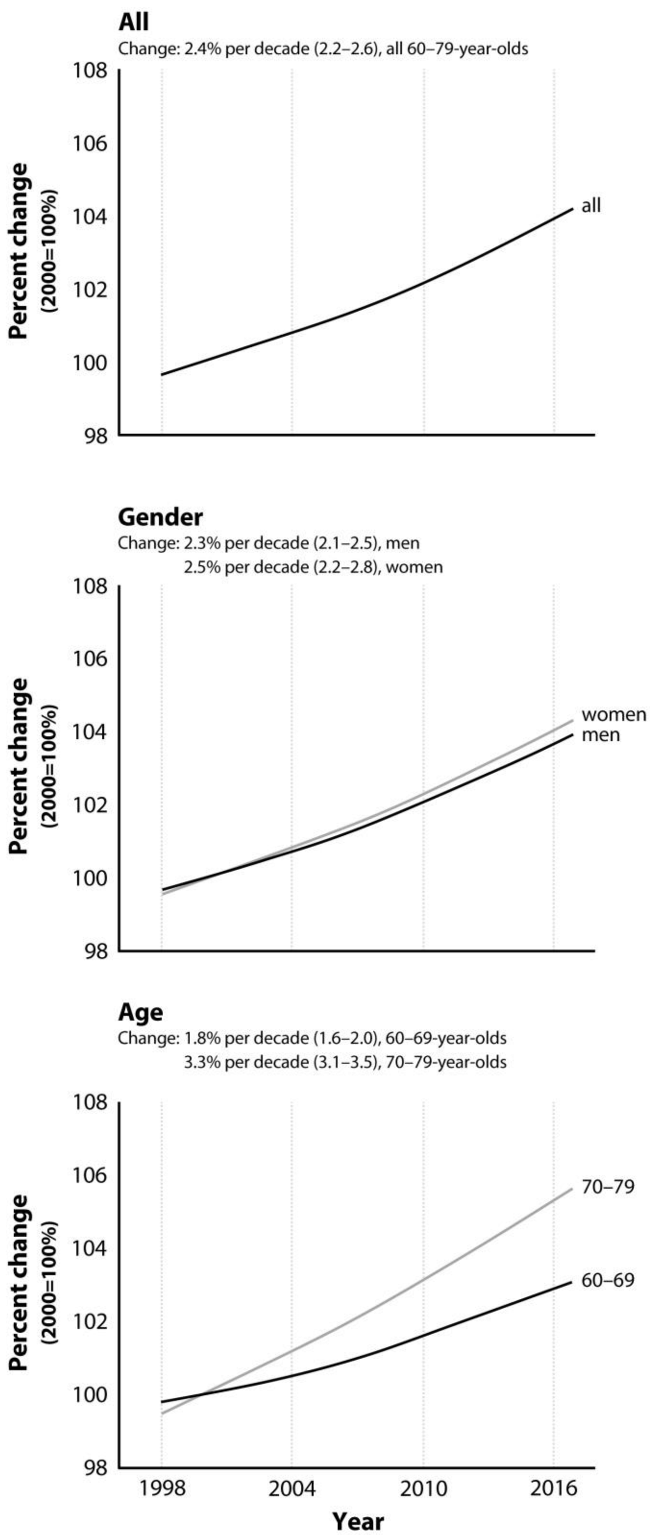

Figure 1