Physical Performance Reference Values for Japanese Oldest Old: A SONIC Study

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Abstract

Background

The oldest old, defined as those aged 90 or over, are now the fastest-growing population sector. This study aimed to determine reference values for a number of physical performance measures (PPMs) among 90-year-olds using internationally standardized measurements and to clarify the characteristics of these indices by comparing their results for 90-year-olds with those for older people ages 70 and 80.

Methods

We used data from the 90-year-olds (88–91) who participated in the Septuagenarians, Octogenarians, and Nonagenarians Investigation with Centenarians (SONIC) study. A total of 789 participants were not certified as needing nursing care and consisted of three survey waves: 2012, 2015, and 2018. For comparison, we also used SONIC respondents from different cohorts, 1,000 who were aged 70 in 2010 and 973 who were aged 80 in 2011. For our physical performance measurements, we used grip strength and score on the Short Physical Performance Battery (SPPB). In addition, we statistically analyzed sex and age differences.

Result

Simple mean ± SD hand grip strength, usual gait speed, five-times chair stand, tandem balance, and SPPB for the 90-year-old respondents were 24.1 ± 5.4 kg, 0.80 ± 0.22 m/s, 17.2 ± 6.73 s, 5.89 ± 4.42 s, and 8.3 ± 2.2, respectively, in men and 14.4 ± 4.0 kg, 0.72 ± 0.20 m/s, 17.8 ± 7.89 s, 4.72 ± 4.35 s, and 7.5 ± 2.4, respectively, in women. For all PPMs, the age 90 cohort was statistically significantly different from the age 70 and 80 cohorts (all trends $P < 0.001$). Grip strength decreased with a similar gradient with age cohort increase of 10 years for both sexes. In contrast, SPPB lower limb score showed a larger drop between the age 80 and 90 cohorts than between the age 70 and 80 cohorts. We also constructed sex-specific appraisal standards according to quintiles.

Conclusions

Our study yielded inclusive sex-specific reference values and appraisal standards for major physical performance measures in not certified as needing nursing care, community-dwelling, oldest old Japanese. The characteristics of age-related decline in physical performance differed between the upper and lower extremity assessments.

Background

The decline in physical performance with aging is a very important issue for older adults because such declines limit older citizens' activities of daily living (ADLs) and instrumental activities of daily living (IADLs). These limitations in turn inhibit independence and autonomy, which decreases overall quality of life. Particular to the population of the oldest old, it takes them a great deal longer to recover from illness and fracture than it does younger people [(1)], so it is important to detect declines in physical performance early and offer appropriate interventions, such as exercise and therapy.

In the United States and Japan, where the aging populations have grown, a new term has been proposed for people aged 90 years or older: the oldest old; this new designation is based on the increase in the number of oldest old people and their current status [(2),(3)]. In developed countries with aging societies, the number of residents in both countries who are over age 90 is rapidly increasing, and this trend is expected to continue and spread to developing countries [(4)].

The Georgia Centenarian Study compared centenarians in Tokyo and Georgia and found that those in Tokyo had lower physical functioning than those in Georgia, with the researchers identifying differences in medical care, living conditions, disabilities, and health status between the two countries as reasons for the differences in functioning [(5)]. Further examining the subject will require evaluating physical functioning in the oldest members of society including those aged 90. As the latter group continues to increase in populations around the world, establishing reference points for functioning in the oldest old will be critical for assessing whether pathological physical declines are taking place.

Many if not most studies of the oldest old have been conducted in Europe and the United States [(5)(6)(7)(8)(9)(10)(11)], and because the subjects of these studies were Europeans, who are taller and heavier than Japanese and other Asians, it is difficult to use them as a reference for comparison with Asians. Therefore, the Asian Working Group for Sarcopenia (AWGS) advocated establishing separate cutoff values that take into account the body size of Asians from the EUROPE criteria [(12)] and establishing cutoffs for physical performance that match the current status of aging in each country [(13),(14)]. In addition to the above research deficiencies, other researchers tend to bundle their results for nonagenarians (people in their 90s) with results for study participants aged 80 or 85 or older [(15)]. Even in studies of people aged 90 and older, researchers do not make comparisons with other age groups or examine their characteristics, and only some report on physical performance indicators in 90-year-olds [(16),(17),(18),(19)]. These various gaps in the literature mean that there are no published reference values for physical performance measures (PPMs) in the age group of 90 and above, which manifests in a few ways. For instance, most researchers assume that the oldest old are frail or weak [(20)(21)(22)], but some set unduly high goals for this group and recommend excessive exercise and treatment. Without effective reference values, there is no accumulation of evidence on preventive and therapeutic interventions for the growing population of the oldest old.

Purpose of this study

Based on the above, the first objective of this study was to propose reference PPMs specifically for individuals aged 90 or above, who traditionally have been grouped with younger elderly populations. The second purpose was to compare the reference values for age 90 with those for ages 70 and 80 and to clarify the differences and characteristics of this age group from other age groups of older adults.

Methods

Study Characteristics

The first distinguishing feature of this study is that we conducted it with older adults in Asia. Asian countries other than Japan are in the transition stage to aging societies, and the numbers of the oldest old are small and of little interest. Ours is a unique assessment of physical performance in the oldest old within Japan specifically. The second distinguishing feature of our study is that we treat age 90 as a discrete group, not just as members of groups age 80 or 85 and above. As we have seen, there are currently no reference values for assessing the physical performance of nonagenarians. With this background, we included 90-year-olds as an independent age cohort.

Participants

The participants in this study were community-dwelling, independently living people who participated in a study of health and longevity called the Septuagenarians, Octogenarians, Nonagenarians Investigation with Centenarians (SONIC), an ongoing prospective cohort study of older people as part of the Centenarian Study initiated in June 2010 [(23)]. The SONIC study aims to assess the characteristics of a general population sample of older people consisting of three control groups of different ages (70s, 80s, and 90s) for a centenarian cohort and to clarify the factors for health, longevity, and psychological well-being. We conducted this study in two main regions of Japan, eastern and western (Tokyo metropolitan area and Hyogo Prefecture, respectively). Both regions include urban and rural areas.

We used data from the SONIC respondents who were ages 88–91 years old. From 10,441 survey subjects, we included 807 onsite participants; we excluded 3,327 mail-only responses from 4,134 mail participants. Of the 807 onsite participants aged 90 years, we excluded 18 who could not complete all physical function tests, leaving 789 participants from the different survey waves: 264 in 2012 (119 men and 145 women), 264 in 2015 (131 men and 133 women), and 261 in 2018 (135 men and 126 women). In 2012, there were no restrictions on the conditions for participation, but in 2015 and 2018, the conditions for participation were set to exclude those who required nursing care and could not walk independently. After we excluded 89 people who had been certified as needing care and 10 who were missing care insurance certification data, we were left with 690 study participants (344 males and 346 females) to use to establish physical performance reference values. Figure 1 presents a flow chart of the details of study participant selection. To compare physical functioning in different age groups of older adults, we also used 1,000 participants aged 70 years (479 men and 521 women) from the 2010 SONIC wave and 973 aged 80 (460 men and 513 women) from 2011.

Methods for assessing physical performance

Difficulties in assessing physical performance in the oldest old

In previous surveys of the oldest old, researchers have used various methods to assess their physical performance. Some researchers have used objective measurements such as gait speed and grip strength that are used with the younger elderly to evaluate the oldest old, and some measure functioning based on survey scores related to IADL performance [(20),(21)]. In all cases, researchers use fewer tests to measure physical performance in the oldest old because this population is at high risk of falls and injuries, making it difficult to apply the same assessment methods as those used for the younger elderly [(22)].

What are the minimum items that can measure physical performance?

As we noted above, researchers have used a wide mix of items to evaluate physical performance in older adults: grip strength, usual and maximum gait speed, the one-legged balance test, the timed up and go (TUG) test, and the Short Physical Performance Battery (SPPB), a comprehensive evaluation of lower limb function using multiple tests [(26),(27),(28)]. However, it is difficult to apply the one-legged balance test and the TUG test to the oldest old due to the high risk of falling.

Among the above measures, researchers in Europe and the United States have used the SPPB to evaluate physical performance in frail elderly populations [(29)]. Even the oldest old can perform it without difficulty, and it has been validated to predict a wide range of indicators such as mortality and nursing care status [(26),(27)]. In addition, grip strength and gait speed are widely used measures for evaluating physical performance regardless of region or age, including in evaluating for sarcopenia, a common frailty in older adults [(18),(28),(29)]. Researchers have used grip strength in particular to evaluate muscle strength even in age groups other than the elderly; it has been shown to be the most predictive and valid indicator for all-cause mortality [(34)]. Building on these earlier research challenges and limitations, we chose to measure physical performance in a population aged 90 and above using scores for grip strength and the SPPB as the basis.

SPPB

Researchers on the SONIC study use the SPPB to assess physical function in the oldest old because it is simple to use, and grip strength to assess muscle strength. Higher total SPPB score indicates higher lower limb function. Researchers have determined that SPPB score below 8 points indicates sarcopenia [(35)].

The SPPB measures balance, gait strength, and endurance, each on a scale of 0 to 12 points. Balance is measured as standing balance holding time with the feet aligned horizontally, semi-vertically (semi-tandem), and vertically (tandem). Gait speed is measured by having a participant walk 8 ft. (about 2.44 m) at usual walking speed. Endurance is assessed by measuring the time from sitting in a chair to standing for five repetitions. For this study, we used gait distance of 2.44 m following the original SPPB, and for the chair stand test, we used a chair at the Japanese standard height of 40 cm. We followed the earlier SPPB scoring criteria [(28)].

Hand grip strength

We measured hand grip strength twice with the participant's dominant hand while he or she sat in a chair with the elbow bent at 90º using a Smedley YD-100 hand grip dynamometer (Yagami Ltd., Tokyo, Japan) up to 1/10th of a kilogram. If the participant could not use the dominant hand to grasp, whether because of a fracture or for other reasons, we used the nondominant one. For maximum grip strength, we used the stronger of the two measurements.

Assessing health-related information

We measured height and weight at the site and calculated body mass index (kg/m^2). We collected other information, medical history, self-rated health, and drinking and smoking history, using self-administered questionnaires.

ADLs and IADLs

There are two methods for evaluating functioning in the elderly. Basic ADLs include walking, moving, eating, and bathing, and higher-order IADLs include managing transportation, meal preparation, medication, and finance. We used the Barthel Index [(36)], a widely used measure for assessment and rehabilitation, to assess the study participants' basic ADL functioning.

To measure IADLs, we used the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC). Lawton systematized seven activity skill levels required for the elderly to live independently in the community, and based on those skills, Koyano et al. developed the TMIG-IC; now, it is widely used for measuring IADLs in Japan [(37)]. There are 13 yes-no questions with 1 point given for each yes, for a score range of 0 to 13 points; higher scores indicate higher functioning.

Statistical Analysis.

We used descriptive statistics to characterize the study population by means and standard deviations. We analyzed differences between men and women using the unpaired T test, chi-squared test, and Mann-Whitney U test and calculated PPM means and standard deviations (SDs) for all 90-year-olds and for each sex. To compare linear trends in the PPM means within the age cohort, we used one-way analyses of variance by sex. We also calculated gait speed at usual paces normalized for height (computed as speed or length divided by height in meters) because height is a predictor of gait speed [(38)]. Similarly, we normalized grip strength for weight (computed as strength in kg divided by weight in kg). We used quintiles of each PPM to construct appraisal standards according to sex for age 90. We set significance at $P < .05$ and performed all statistical analyses using IBM SPSS Statistics version 25.

Result

Table 1 shows the number of participants who were unable to perform each PPM and those who had difficulty with the five-times sit-to-stand test, which took more than 20 s. The percentages of unusable data were 2.1% (n = 17 participants), 6.7% (n = 17), 19.7% (n = 158), and 6.6% (n = 53) for grip strength, usual gait speed, sit-to-stand test, and tandem balance, respectively. The number of people who took more than 20 s to stand up from a chair five times was 168, or 20.8% of the total. The lowest and highest rates of missing data were for grip strength and the five-times sit-to-stand test, respectively.

Table 1. Numbers of participants with unable data for each variable.

Variables	age 70		80		90	
	unable, (%)	difficulty,(%)	unable, (%)	difficulty,(%)	unable, (%)	difficulty,(%)
Physical performance measures						
Hand grip strength	16 (1.6)	-	5 (0.5)	-	17 (2.1)	-
Usual gait speed	15 (1.5)	-	14 (1.4)	-	54 (6.7)	-
Tandem balance	2 (0.2)	-	12 (1.2)	-	53 (6.6)	-
5times chair stand	16 (1.6)	1 * (0.1)	46 (4.7)	32 *(3.3)	158 (19.7)	168 *(20.9)

*5times chair stand >20sec

Table 2 summarizes the characteristics of the 90-year-old study participants. All PPMs were significantly higher in men than in women, except for the sit-to-stand test. Men had significantly higher ADL scores than women did, but there were no statistically significant differences between men and women on the IADLs.

Tables 3 and 4 present unweighted simple PPM means and SDs according to age group in men and women, respectively. For all PPMs, the age 90 cohort was statistically significantly different from the age 70 and 80 cohorts (all trends $P < 0.001$). In women, all PPMs showed a significant decreasing trend as the age cohort increased. In contrast, there were no statistically significant differences in height-adjusted gait speed, chair stand, tandem balance, or SPPB total score between male 70- and 80-year-olds.

Grip strength decreased equitably with a similar slope (difference between ages 70–80 and 80–90: M 4.79, 4.03; W 2.84, 2.67) with increasing 10-year age cohort for both sexes. In contrast, usual gait speed, tandem balance, and SPPB total score (difference between ages 70–80 and 80–90: M 0.18, 2.26; W 0.76, 2.57) showed a larger drop between the 80–90 age cohort than the drop between the 70–80 age cohort. Finally, Table 5 shows the PPM quintiles for men and women of age 90 excluding those who required nursing care. Although we found a ceiling effect in tandem balance in men, all other PPMs had an approximately symmetrical distribution.

We calculated means for each physical function assessment by sex for the 90-year-old subjects, used these means as reference values, and constructed sex-specific evaluation criteria according to the quintiles. The means and SDs for grip strength, normal gait speed, tandem balance, five-times sit-to-stand test, and total SPPB scores for 90-year-old Japanese adults were as follows: 24.1 (5.40) kg, 0.80 (0.22) m/s, 5.9 (4.42) s, 17.2 (17.2) s, and 8.3 (2.21), respectively, in men and 14.4 (4.03) kg, 0.72 (0.20) m/s, 4.7 (4.35) s, 17.8 (7.89) s, and 7.5 (2.39), respectively, in women.

Table 2. Characteristics of All Study Participants

Variables		Mean ± standard devation or n (%)		p
		Men (n = 1324)	Women (n = 1438)	
Age cohort, n (%)				
	70	479 (47.9)	521 (52.1)	
	80	460 (47.3)	513 (52.7)	
	90	385 (48.8)	404 (51.2)	
aged 90		Men (n = 385)	Women (n = 404)	
recruit year				
	2012	119 (45.1)	145 (54.9)	
	2015	131 (49.6)	133 (50.4)	
	2018	135 (51.7)	126 (48.3)	
Geographic area, n (%)				
Urban	Itami	127 (50.8)	123 (49.2)	
	Itabashi	132 (42.0)	182 (58.0)	
Rural	Asago	77 (55.0)	63 (45.0)	
	Okutama	49 (57.6)	36 (42.4)	
Heighet, cm		158.8 (6.1)	144.9 (6.1)	< 0.001
Weight, kg		55.7 (8.3)	45.8 (7.4)	< 0.001
long-term care insurance certification, n (%)		36 (9.4)	53 (13.3)	0.087
Body mass index, kg/m2		22.1 (2.9)	21.8 (3.2)	0.207
Chronic disease, n (%)				
Hypertension		249 (65.0)	282 (70.0)	0.137
Dementia		15 (4.1)	19 (5.1)	0.807
Stroke		45 (11.7)	30 (7.5)	0.083
Perkinnson's disease		2 (0.5)	1 (0.2)	0.535
Heart disease		133 (34.5)	120 (29.7)	0.145
diabetes *mellitus*		58 (15.1)	51 (12.7)	0.320
Self-rated health, n (%)				
Excellent to good		304 (79.2)	328 (81.8)	0.362
Fair to poor		80 (20.8)	73 (18.2)	
Alcohol drinking status, n (%)				
Current		179 (45.5)	45 (10.7)	< 0.001
Past		68 (25.3)	25 (14.0)	< 0.001
Smoking status, n (%)				
Current		31 (7.8)	10 (2.4)	< 0.001
Past		279 (71.5)	32 (7.7)	< 0.001
Barthel Index (ADL)		96.47 ± 8.80	93.36 ± 12.23	< 0.001
TMIG-IC (IADL)		6.27 ± 3.18	6.12 ± 3.44	0.535
Physical performance measures				
Hand-grip strength, kg		23.7± 5.69	14.1 ± 4.13	< 0.001
Usual gait speed, m/s		0.78 ± 0.22	0.70 ± 0.21	< 0.001
Tandem balance, sec		5.7 ± 4.45	4.3 ± 4.33	< 0.001
5times chair stand, sec		17.1 ± 6.83	17.9 ± 7.86	0.156
SPPB total score		8.2 ± 2.33	7.3 ± 2.51	< 0.001

Tabel 3. Descriptive statistics for physical performance measures according to age group (men).

Varriables	Mean ± standard devision				*p* for trend
		Age group			
	Overall	70	80	90	
Hand grip strength, kg	28.8 ± 6.9	32.9 ± 6.6	28.1 ± 5.7	24.1 ± 5.4	< 0.001
Weight-adjusted hand-grip strength [stength (kg)/ weight (kg)]	0.49 ± 0.11	0.53 ± 0.11	0.48 ± 0.10	0.44 ± 0.10	< 0.001
(n)	(1259)	(471)	(444)	(344)	
Usual Gait speed, m/s	0.90 ± 0.22	0.96 ± 0.23	0.91 ± 0.20	0.80 ± 0.22	< 0.001
Hight-adjusted usual gate speed [speed (m/s)/ height (m)]	0.55 ± 0.14	0.58 ± 0.14	0.56 ± 0.12	0.50 ± 0.14	< 0.001
(n)	(1250)	(471)	(414)	(336)	
5times chair stand, sec	13.53 ± 5.0	12.2 ± 3.32	12.3 ± 3.47	17.2 ± 6.73	< 0.001
(n)	(1217)	(468)	(436)	(313)	
Tandem balance, sec	8.26 ± 3.49	9.39 ± 2.19	9.26 ± 2.31	5.89 ± 4.42	< 0.001
(n)	(1255)	(478)	(442)	(335)	
SPPB tonal score	10.1 ± 2.0	10.8 ± 1.4	10.6 ± 1.6	8.3 ± 2.2	< 0.001
(n)	(1250)	(471)	(443)	(336)	

Tabel 4. Descriptive statistics for physical performance measures accorsing to age group (women)

Varriables	Mean ± standard devision				*p* for trend
		Age group			
	Overall	70	80	90	
Hand grip strength, kg	17.5 ± 4.9	19.9 ± 4.8	17.1 ± 4.3	14.4 ± 4.0	< 0.001
Weight-adjusted hand-grip strength [stength (kg)/ weight (kg)]	0.36 ± 0.10	0.38 ± 0.10	0.35 ± 0.09	0.31 ± 0.09	< 0.001
(n)	(1358)	(513)	(499)	(346)	
Usual Gait speed, m/s	0.88 ± 0.23	0.99 ± 0.22	0.88 ± 0.21	0.72 ± 0.20	< 0.001
Hight-adjusted usual gate speed [speed (m/s)/ height (m)]	0.59 ± 0.15	0.65 ± 0.14	0.60 ± 0.14	0.50 ± 0.14	< 0.001
(n)	(1343)	(514)	(495)	(334)	
5times chair stand, sec	13.35 ± 5.37	11.7 ± 3.46	12.6 ± 3.56	17.8 ± 7.89	< 0.001
(n)	(1263)	(516)	(472)	(275)	
Tandem balance, sec	7.53 ± 3.97	9.20 ± 2.46	8.23 ± 3.45	4.72 ± 4.35	< 0.001
(n)	(1348)	(521)	(496)	(331)	
SPPB tonal score	9.77 ± 2.3	10.9 ± 1.3	10.1 ± 1.9	7.5 ± 2.4	< 0.001
(n)	(1346)	(516)	(497)	(333)	

Table 5. Quintiles of physical performance measures for 90 years old

Physical performance measures	**Quintile levels**		**Men**		**Women**	
Hand-grip strength (kg)			n = 344	mean	n = 346	mean
	5	(Highest)	**28.0** <=		**17.5** <=	
	4		25.0-27.9		15.5-17.4	
	3		22.5-24.9	**24.1**	13.0-15.4	**14.4**
	2		19.5-22.4		11.0-12.9	
	1	(Lowest)	< **19.5**		< **11.0**	
Usual gait speed (m/s)			n = 336		n = 334	
	5	(Highest)	**1.00**<=		**0.88** <=	
	4		0.83 - 0.99		0.77 - 0.87	
	3		0.72 - 0.82	**0.80**	0.68- 0.76	**0.72**
	2		0.63 - 0.71		0.54 - 0.67	
	1	(Lowest)	< **0.63**		< **0.54**	
Tandem balance (s)			n = 335		n = 331	
	5	(Highest)	**10** <=		**10** <=	
	4		10 <=		7.2 - 9.9	
	3		4.0 - 10.0	**5.9**	1.9 - 7.1	**4.7**
	2		0.1 - 3.9		0.1 - 1.8	
	1	(Lowest)	**0**		**0**	
5 times chair stand (s)			n = 313		n = 275	
	5	(Highest)	<= **12.3**		<= **12.8**	
	4		14.6-12.4		15.0 - 12.9	
	3		17.0-14.7	**17.2**	18.0 - 15.1	**17.8**
	2		21.0-17.1		22.0 - 18.1	
	1	(Lowest)	**21.0** <		**22.0** <	
SPPB total score			n = 336		n = 333	
	5	(Highest)	**10** <=		**10** <=	
	4		9		8 □9	
	3		8	**8.3**	7	**7.5**
	2		7		6	
	1	(Lowest)	<= **6**		<= **5**	

*Participants, except for those who are certified as long-term care need

Discussion

Main findings

The results of this study showed that grip strength decreased at a similar slope in each age group as the age group increased. In contrast, total SPPB score, an indicator of lower limb muscle strength, showed a greater drop between ages 80 and 90 than between ages 70 and 80. This suggests a rapid decline in physical function, especially in the lower limbs, during the transition from age 80 to age 90, the age of the oldest old.

Grip strength indicates a decline in total muscle strength, which gradually declines with aging. On the other hand, SPPB scores include not only muscle strength of the lower limbs, but also the state of functional aspects such as gait and balance in the figures. Therefore, it is possible that the SPPB is also influenced by the frequency of daily activities (standing up, moving), etc. The rapid decline in lower limb function at age 90 is assumed to be due to much less outdoor mobility, such as fewer outings and participation in organizations.

The present results versus previous study findings

Table 6 presents a comparison of the findings from earlier large-scale cohort studies of physical functioning in elderly populations. The participants in the BFC80+ [(39)], the Leiden 85-Plus [(40)], the Tokyo Metropolitan Institute of Gerontology-Longitudinal Interdisciplinary Study on Aging (TMIG-LISA) 6 cohort study [(15)], and the Newcastle 85-Plus Study [(41)] were 85 to 89 years old; the BFC80+ included 85-year-olds; and the others included minimum 85 years up to over age 90. The participants in the 90+ Study [(16)], the validity 90+ Study [(17)], the Danish 1905 cohort survey [(18)], and Genetics of Healthy Aging (GEHA) [(42)] studies were age 90 or older. The GEHA physical function assessment study was conducted in Italy with a large number of subjects (more than 1,000), similar to the Danish 1905 cohort survey. Only the validity 90+ Study targeted 90-year-olds; the others had a mixture of subjects aged 90 years and older. The TMIG-LISA 6 cohort study had similar participation rates for men and women [(15)], but the overall sample size was smaller than the other studies at 116 participants. The other studies had more than 1.5 times more women than men.

Table 6. Assessment of physical performance in previous studies of the oldest old (85 years and older)

	85 to 90 years old				90 years old over				
reserch name	The BFC80+	The Liden 85-plus	TMIG-LISA 6 cohort study	The Newcastle 85-plus Study	The 90+ Study	Vaitality 90 + study	The Danish 1905 cohort survey 1998	GEHA	peresent study
country	Belgium	Netherland	Japan	UK	USA	Finland	Denmark	Italia	Japan
age	85	85-89	85 over	85-90	94	90	92-93	90-94	90
Sex (number)	M (211) W (356)	M (102) W (255)	M (48) W (68)	M (106) W (188)	M (173) W (456)	M (65) W (197)	M (491)W (1307)	M (369) W (791)	M (344) W(346)
grip strength (kg)	M 30.6 W 17.8	M 25.6 W 16.4	M 23.2 W 15.2	M 21.05 W 11.5	M 20.3 W 11.1*	M 46* W 28* *median value	M 22.8 W 13.4	M 22.0 W 13.5	M 24.1 W 14.4
gait speed (m/s)	M 0.7 W 0.5	ALL 0.52	M 1.11 W 0.92	–	M 0.66 W 0.52*	–	M 0.64 W 0.52	–	M 0.8 W 0.72
5times Chair stand (sec)	–	–	–	–	M 16.2 W 16.8*	M 18.0 W 20.0	–	–	M 17.2 W 17.8
SPPB	M 8.4 W 6.3*	–	–	–	modified SPPB	–	–	–	M 8.3 W 7.5
Remarks	Max gate speed *modified SPPB	Max gate speed	Gate speed with acceleration phase	timed and go test 3m 18.7	*Values in the middle quartile	Walking ability (mobility) was interviewed by questionnaire	usual gate speed	Walking ability (mobility) was interviewed by questionnaire	the original SPPB evaluation was used.

Grip strength

In this study, grip strength decreased as age increased for both men and women, which was consistent with earlier findings among the elderly in Japan [(43)]. In previous studies conducted in Europe, the average grip strength of men and women in the Newcastle 85-Plus Study [(41)] (mean age 90) were 21.05kg and 11.5kg respectively, compared with our findings of 24.1kg men and 14.4kg women, and the average in the Leiden 85-Plus Study [(40)] (mean age 89) were 25.6kg men and 16.4kg women. That is, we had higher value than in the UK study and lower than in the Dutch Leiden study, and these variations reflect the overall inconsistency in research findings on the oldest old age 90 and over.

Usual gait speed

For usual gait speed per second in this study, the rates for men (0.8 m/s) and women (0.72) were higher than the overall gait speeds in the Leiden 85-Plus (all: 0.52 m/s) [(40)] and BFC80+ [(39)] (age 85; M: 0.7 m/s, W: 0.5 m/s), which used respondents at a younger average age than the subjects in the present study. The usual gait speeds we found were faster than those in the 90 + Study [(16)] (ages 90–94; M: 0.66, W: 0.52), which used older participants than ours, and those in the Danish 1905 cohort survey (ages 92–93; M: 0.64, W: 0.52), whose participants were also older. In contrast, the present gait speeds were slower than the speeds in the TMIG-LISA 6 cohort study [(44)] (M: 1.11 m/s, W: 0.92 m/s), which was conducted in Japan on the elderly over age 85.

Usual and maximal gait speed

The Leiden 85-Plus (age 89) and BFC80+ (age 85), both study cohorts younger than the SONIC's, measured maximum gait speed, while the other studies (90 + Study, Danish 1905) measured usual gait speed. Because maximum gait speed is generally faster than usual speed, the fact that our findings for usual gait speed were faster than the maximum gait speeds in other studies indicates a faster gait speed in the oldest of Japanese individuals than the speed of the oldest old in the West.

Chair stand

The speeds in this study for the five-times sit-and-stand test (M: 15.9 and W: 16.3 × the upper limit of quartile 3 compared with the 90 + Study) were faster than those in the validity 90 + Study (M: 18.0, W: 20.0) for the same age group and those in the 90 + Study (M: 16.1, W: 16.7). In addition, the differences between men and women in the results of this study were small, and there was no statistically significant gender difference in the results in the 90-year-old reference value (3rd normal quintile). In addition, women in the SONIC study were faster in the 70-year-old age cohort.

Possible causes for value differences

When comparing the results of different studies on evaluating physical functions, it is important to use the same measurement methods. The differences between our results and those of previous studies might be attributed to the differences in measurement methods. Here we discuss possible causes for differences between studies in the evaluated PPMs and propose research directions for future studies focusing on the oldest old.

Grip strength

Grip strength varies depending on standing versus sitting, upper limb position, and forearm posture, so appropriate comparisons require similar measurement methods. In this study, we used the measurement method recommended by the American Society of Hand Therapists [(45)], whereby participants were required to sit, rotate their shoulders inward to a neutral position, bend their elbows to 90°, place their forearms in a neutral position, and dorsiflex their wrists between 0° and 30°. In populations other than solely older adults, grip strength in Japan is often measured in a standing position with the elbow extended, and there are few measurement data on older adults in a sitting position [(46)].

In examinations of differences in grip strength by posture, researchers found greater grip strength in the standing position than in people who were seated [(45)]. In previous studies, some researchers measured grip while standing, and some did not mention the measurement posture. These differences in measurement methods could have affected the results of comparing studies.

It is often difficult for oldest old people over age 90 to hold a standing position. In fact, about 20% of the 90-year-old participants in the SONIC study needed some kind of assistance to stand up and to hold the standing position, and it was difficult to measure their ability to stand up from a chair. Not only the oldest old but also those who cannot hold a standing position are expected to have weaker grip (muscle) strength than those who can hold a standing position without holding anything. Therefore, a participant's ability to hold the standing position is a prerequisite for measuring grip strength, which can cause selection bias; studies might show high findings because the authors selected people with high muscle strength. Similarly, some investigators measured grip strength in an unstable state in which the subject held the balance with one hand while standing. In the Leiden 85-Plus, where the grip strength was greater than in the present study, 14.8% of the subjects could not be measured, and it is possible that those results were influenced by selection bias because people who could not stably hold the standing position were excluded from the measurement.

In short, the effect of measurement position on 90-year-olds is significant due to their physical vulnerability, and therefore, when comparing PPMs, it is important to consider the measurement method (such as measurement position and frequency) more strictly than is generally necessary with older adult. The oldest old often have difficulty maintaining a standing position and are at greater risk of falling, which suggests that it is safer and more stable to measure grip strength of the oldest old in a sitting posture.

Gait speed

Gait is a method of assessing physical function that many researchers have used in studies of older adults. Although many standardized data on gait speed have been published, the most common one is usual gait speed, which is highly sensitive in predicting ADL disability in people over 75 years old [(46)]. For this study, we measured gait following Guralnik's original SPPB gait measurement method [(28)]. That is, we used a static start method in which we measured normal gait speed from the starting line within a frame of 8 ft. (2.44 m) without an acceleration period. In many cases, 90-year-olds are unable to participate in surveys outside their homes due to their declining physical functioning. We adopted a gait distance of 2.44 m in this study because we considered that oldest old citizens who were in institutions or who could not come to the survey site could measure their gaits at the places where they lived. Since the advent of the COVID-19 pandemic in 2020, group surveys conducted in large venues have been severely restricted to prevent infection, and such restrictions are expected to continue in the future. Because the SPPB can be measured at home or in a facility with limited space, we considered it appropriate for measuring physical function in 90-year-olds even during the pandemic.

The gait distance was 3 m in the Danish 1905 cohort survey and the BFC80 + and 4 m in the 90 + Study, and we believe that the researchers used these short distances in part because of the ease of measurement in facilities and homes. As the age of the elderly increases, the maximum gait speed slows down, and the effect of the acceleration period becomes relatively small [(47)]. Thus, we consider that lower limb function in the oldest old can be appropriately assessed even by walking a short distance.

Researchers in Japan commonly use dynamic start with an acceleration period before the measurement distance, whereas Western researchers commonly use a static start without an acceleration period. The dynamic start is faster because it reduces the influence of the slow acceleration period. Because studies on Japanese elderly people including the TMIG-LISA 6 cohort study used dynamic start [(44)], it is not possible to accurately compare Japanese findings with findings from overseas studies. However, with the present study, we used the static start method, and thus, we consider that our findings are comparable with those from Western studies. This is the first study to report walking speed by gender in Japanese subjects aged 90 years who were not certified as needing long-term care using an internationally standardized measurement method.

Chair stand and chair height

It is possible that the height of the chair had an advantage for Japanese women, who are shorter than those in Europe and the United States and than men. One of the factors that affects standing behavior is the height of the chair used for measurement [(48)]. In the SONIC study, a Japanese standard chair height of 40 cm was used for both men and women, and because women are shorter than men, a chair of the same height would make it relatively easier for women to stand up and harder for men. This could be why there was little difference between men and women on the five-times sit-and-stand test.

It is also possible that the differences in chair heights used between the studies in Europe, the United States, and Japan could have affected the rise times in this study in addition to the differences. However, we could not verify this proposition because researchers on the previous studies did not include the heights of the chairs used. Therefore, accurately comparing rising data internationally requires noting and considering differences in the chair heights used.

Differences in lifestyles

Research has established that differences in walking speed are attributable to differences in lifestyle. In the case of this study, we assumed that the differences in walking speed from findings in other studies were attributable to that people in Japan who tend to live a tatami mat lifestyle; that is, they regularly stand up and sit down each day, which strengthens their lower limbs on a daily basis [(49)]. In Japan, many elderly people continue to live on tatami mats until they require nursing care, when it is common for them to change to chairs or beds. It is necessary to further investigate whether similar cultural factors and lifestyle features affect ADLs and other measurements of functioning in the oldest old in different countries.

Standing itself as a screening criterion

In this study, the proportions of participants who failed or were unable to perform the five-times sit-and-stand test was the largest among the tests of physical performance assessment: 1.6% in the age 70 cohort, 4.7% in age 80, and about 20% in age 90. In other words, the percentage of 90-year-olds who were unable to perform the test five times was much higher than that of other age cohort.

Furthermore, compared between PPMs, the proportion of 90-year-olds who could not complete the chair stand test failure (19.7%) was larger than those for grip strength (2.1%) and normal gait speed (6.7%) among the other tests. In addition, 20.9% of the subjects took longer than 20 s to perform the test (Table 1). This means that at the age of 90, the test of standing up from a chair proves to be remarkably difficult.

In the Danish cohort survey of nonagenarians, 61% of men and 50% of women were able to stand up without using their hands [(18)]; in other words, 39% of men and half of women could not stand up without using their hands. Similarly, in the 90 + Study, 32% of all participants failed to complete the five-times sit-and-stand test. These results indicate significantly higher proportions of people who have difficulty standing up without using their hands in the oldest old (90 years and older) than in younger old age groups.

Guralnik originally gave an SPPB score of 0 for failures to complete the five-times sit-stand and a score of 1 to the lowest 25% of those who completed the test [(28)]. Based on the results of this study and of previous studies, it is possible that about one quarter of the oldest old are unable to rise from a chair without holding on to something, which corresponds to the lower approximately 25% of the total oldest old population to the criterion for 1 point on the original SPPB. Therefore, the five-times sit-to-stand test could be a screening test for lower limb muscle strength. Indeed, the AWGS, in its 2019 criteria for the diagnosis of sarcopenia, allows general practices and facilities to use the test if they do not have dual-energy X-ray absorption or bioelectrical impedance analysis [(14)].

Researchers on a study of elderly people in Japan used a test called the Frail 10-Second Chair Stand Test to measure the number of times a person could stand up in 10 s without using their hands in a similar way to the SPPB and found that it was independently associated with quadriceps strength and TUG test score, which represents dynamic balance [(50)]. These findings suggest that the chair stand test can be used to assess overall lower extremity muscle strength even when used alone in the oldest old over 90 years of age (in Japan).

Study strengths and limitations

The main limitation in this study was selection bias. The subjects in this study were 90-year-olds who were not certified as needing long-term care who were otherwise eligible to participate, but according to the 2015 census, approximately 50% of Japanese aged 90 and older are certified as needing long-term care in an institution [51]. Therefore, we believe we can assume that the participants in this study were relatively healthy community-dwelling 90-year-olds, and the distribution of physical functions across all 90-year-olds can be estimated by adding assessments that include those certified as requiring long-term care. In addition, as mentioned in the discussion, we grouped the three populations from different participation years, so it is necessary to consider the rejuvenation phenomenon separately among these populations. Finally, due to the cross-sectional design of this study, it was not possible to make causal inferences about age or sex differences in PPMs.

The main strength of this study is that we had access to a large sample size of the oldest old over 90 years of age one country in Asia, where there are still few oldest old people; generally, there are fewer oldest old men than women, but rates in this study were similar: 48.8% for men and 51.2% for women. Furthermore, the results of this study can be easily compared with other studies because we assessed physical function using internationally standardized measurement methods. At the present stage, there are no better representative data for Asia's oldest old, including in Japan, and this is why we believe our results can be used as the best current reference values for the oldest old people in Asian countries.

Conclusions

This study was an analysis of sex-specific reference values and appraisal standards for five PPMs in nondisabled, community-dwelling, Japanese oldest old (age 90 and over). Although absolute physical performance varies among populations, the age and sex differences in PPMs could be common across Asian countries. The characteristics of this results in PPMs can be broadly shared not only with Japan but also with Asian countries.

Declarations

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Ethics approval and consent to participate

The SONIC study was approved by the Institutional Review Board of Osaka University Graduate School of Medicine, Dentistry, and Human Sciences (Osaka, Japan) and the Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology (Tokyo, Japan). This Research was performed in accordance with the Declaration of Helsinki. Informed consent was obtained from all study participants on site prior to starting the survey. Participation of this study was voluntary. was voluntary. We explained the aims, methods, sources of funding, any possible conflicts of interest, institutional affiliations of the researcher, the anticipated benefits and potential risks of the study and the discomfort it may entail, post-study provisions. And we gave all participants that they had the right to refuse to participate in the study or to withdraw consent to participate at any time without reprisal. Participants have been informed of the research, and they have given their written consent. Their anonymity has been guaranteed.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

KM, SY, and YG: concept, designed, and developed the overall research plan. KM, YG, YM, SY, YY, KI, YA, MK, KK, HA and TI carried out data collection. KM and YG conducted analysis and KM,YY,and YG interpretation of data. KM, and YG wrote and had responsibility for the final contents of the manuscript. All authors read and approved the final manuscript.

References

1. Covinsky KE, Palmer RM, Fortinsky RH, Counsell SR, Stewart AL, Kresevic D, et al. Loss of Independence in Activities of Daily Living in Older Adults Hospitalized with Medical Illnesses: Increased Vulnerability with Age. JAGS. 2003;51:451–8.
2. He W, Muenchrath MN. 90+ in the United States: 2006-2008 American Community Survey Reports. 2011.

3. Ouchi Y, Rakugi H, Arai H, Akishita M, Ito H, Toba K, et al. Redefining the elderly as aged 75 years and older: Proposal from the Joint Committee of Japan Gerontological Society and the Japan Geriatrics Society. Geriatr Gerontol Int. 2017 Jul 1;17(7):1045–7.
4. United Nations, Department of Economic and Social Affairs PD. World Population Ageing 2017 [Internet]. 2017. Available from: https://www.un.org/en/development/desa/population/theme/ageing/WPA2017.asp
5. Vaes B, Pasquet A, Wallemacq P, Rezzoug N, Mekouar H, Olivier P-A, et al. The BELFRAIL (BF C80 +) study: a population-based prospective cohort study of the very elderly in Belgium. BMC Geriatr [Internet]. 2010;10:39. Available from: http://www.biomedcentral.com/1471-2318/10/39
6. Bootsma-Van Der Wiel A, Van Exel E, De Craen AJM, Gussekloo J, Lagaay AM, Knook DL, et al. A high response is not essential to prevent selection bias: Results from the Leiden 85-plus study. J Clin Epidemiol. 2002;55:1119–25.
7. Collerton J, Barrass K, Bond J, Eccles M, Jagger C, James O, et al. The Newcastle 85+ study: Biological, clinical and psychosocial factors associated with healthy ageing: Study protocol. BMC Geriatr. 2007;7:14.
8. Paganini-Hill A, Kawas CH, Corrada MM. Lifestyle factors and dementia in the oldest-old: The 90 + study. Alzheimer Dis Assoc Disord. 2016;30(1):21–6.
9. Jylhä M, Enroth L, Luukkaala T. Trends of Functioning and Health in Nonagenarians: The Vitality 90+ Study. Annu Rev Gerontol Geriatr. 2013 Feb 24;33(1):313–32.
10. Kjær AA, Siren A, Seestedt MH, Fridberg T, Casier F. Cohort Profile: The Danish Longitudinal Study of Ageing (DLSA). Int J Epidemiol. 2019 Aug 1;48(4):1050-1050G.
11. Skytthe A, Valensin S, Jeune B, Cevenini E, Balard F, Beekman M, et al. Design, recruitment, logistics, and data management of the GEHA (Genetics of Healthy Ageing) project. Exp Gerontol. 2011 Nov;46(11):934–45.
12. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: Revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16–31.
13. Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS, et al. Sarcopenia in Asia: Consensus report of the Asian working group for sarcopenia. J Am Med Dir Assoc [Internet]. 2014;15(2):95–101. Available from: http://dx.doi.org/10.1016/j.jamda.2013.11.025
14. Chen L-K, Woo J, Assantachai P, Auyeung T-W, Chou M-Y, Iijima K et al. Asian working group for sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc. 2020;21(3):300–307.
15. Seino S, Shinkai S, Fujiwara Y, Obuchi S, Yoshida H, Hirano H, et al. Reference values and age and sex differences in physical performance measures for community-dwelling older Japanese: A pooled analysis of six cohort studies. PLoS One. 2014 Jun 12;9(6).
16. Bullain SS, Corrada MM, Shah BA, Mozaffar FH, Panzenboeck M, Kawas CH. Poor physical performance and dementia in the oldest old: The 90+ study. Arch Neurol. 2013;70(1):107–13.

17. Tiainen K, Hurme M, Hervonen A, Luukkaala T, Jylhä M. Inflammatory markers and physical performance among nonagenarians. Journals Gerontol - Ser A Biol Sci Med Sci. 2010 Jun;65(6):658–63.
18. Nybo H, Gaist D, Jeune B, McGue M, Vaupel JW, Christensen K. Functional status and self-rated health in 2,262 nonagenarians: The Danish 1905 cohort survey. J Am Geriatr Soc. 2001;49(5):601–9.
19. Cevenini E, Cotichini R, Stazi MA, Toccaceli V, Palmas MG, Capri M, et al. Health status and 6 years survival of 552 90+ Italian sib-ships recruited within the EU Project GEHA (GEnetics of Healthy Ageing). Age (Omaha). 2014;36(2):949–66.
20. Passarino G, Montesanto A, De Rango F, Garasto S, Berardelli M, Domma F, et al. A cluster analysis to define human aging phenotypes. Biogerontology. 2007 Jun;8(3):283–90.
21. Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS, et al. Sarcopenia in Asia: Consensus report of the Asian working group for sarcopenia. J Am Med Dir Assoc. 2014;15(2):95–101.
22. Cress ME, Gondo Y, Davey A, Anderson S, Kim SH, Poon LW. Assessing physical performance in centenarians: Norms and an extended scale from the Georgia centenarian study. Curr Gerontol Geriatr Res. 2010;2010:6 page.
23. Gondo Y, Masui Y, Kamide K, Ikebe K, Arai Y, Ishizaki T, et al. SONIC Study: A Longitudinal Cohort Study of the Older People as Part of a Centenarian Study. Encycl Geropsychology. 2015;1–10.
24. Ferrer A, Formiga F, Plana-Ripoll O, Tobella MA, Gil A, Pujol R. Risk of falls in 85-year-olds is associated with functional and cognitive status: The Octabaix study. Arch Gerontol Geriatr. 2012 Mar;54(2):352–6.
25. Hao Q, Dong B, Yang M, Dong B, Wei Y. Frailty and cognitive impairment in predicting mortality among oldest-old people. Front Aging Neurosci. 2018 Oct 18;10:295.
26. Richardson P. the Timed & Go. Jags. 1991;39(2):142–8.
27. Cooper R, Kuh D, Cooper C, Gale CR, Lawlor DA, Matthews F, et al. Objective measures of physical capability and subsequent health: A systematic review. Age Ageing. 2011 Jan;40(1):14–23.
28. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A Short Physical Performance Battery Assessing Lower Extremity Function: Association With Self-Reported Disability and Prediction of Mortality and Nursing Home Admission. J Gerontol Med Sci. 1994;49(2):85–94.
29. de Fátima Ribeiro Silva C, Ohara DG, Matos AP, Pinto ACPN, Pegorari MS. Short physical performance battery as a measure of physical performance and mortality predictor in older adults: A comprehensive literature review. Int J Environ Res Public Health. 2021;18(20).
30. Guralnik JM, Ferrucci L, Pieper CF, Leveille SG, Markides KS, Ostir G V., et al. Lower extremity function and subsequent disability: Consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. Journals Gerontol - Ser A Biol Sci Med Sci. 2000;55(4):221–31.
31. Pavasini R, Guralnik J, Brown JC, di Bari M, Cesari M, Landi F, et al. Short Physical Performance Battery and all-cause mortality: Systematic review and meta-analysis. BMC Med. 2016 Dec 22;14(1).

32. Kuh D, Karunananthan S, Bergman H, Cooper R. A life-course approach to healthy ageing: Maintaining physical capability. In: Proceedings of the Nutrition Society. Cambridge University Press; 2014. p. 237–48.
33. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in Older Adults: Evidence for a Phenotype [Internet]. Vol. 56, Journal of Gerontology: MEDICAL SCIENCES Copyright. 2001. Available from: http://biomedgerontology.oxfordjournals.org/
34. Wu Y, Wang W, Liu T, Zhang D. Association of Grip Strength With Risk of All-Cause Mortality, Cardiovascular Diseases, and Cancer in Community-Dwelling Populations: A Meta-analysis of Prospective Cohort Studies. J Am Med Dir Assoc. 2017 Jun 1;18(6):551.e17-551.e35.
35. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis. Age Ageing. 2010;39(4):412–23.
36. Liu W, Unick J, Galik E, Resnick B. Barthel index of activities of daily living: Item response theory analysis of ratings for long-term care residents. Nurs Res. 2015;64(2):88–99.
37. Koyano W, Shibata H, Nakazato K, Haga H, Suyama Y. Measurement of competence: reliability and validity of the TMIG Index of Competence. Arch Gerontol Geriatr [Internet]. 1991 [cited 2012 Jun 1];13(2):103–16. Available from: http://www.sciencedirect.com/science/article/pii/016749439190053S
38. Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: Reference values and determinants. Age Ageing. 1997;26(1):15–9.
39. Legrand D, Adriaensen W, Vaes B, Matheï C, Wallemacq P, Degryse J. The relationship between grip strength and muscle mass (MM), inflammatory biomarkers and physical performance in community-dwelling very old persons. Arch Gerontol Geriatr. 2013 Nov;57(3):345–51.
40. Ling CHY, Taekema D, De Craen AJM, Gussekloo J, Westendorp RGJ, Maier AB. Handgrip strength and mortality in the oldest old population: The Leiden 85-plus study. Can Med Assoc J. 2010 Mar 23;182(5):429–35.
41. Granic A, Mendonça N, Sayer AA, Hill TR, Davies K, Adamson A, et al. Low protein intake, muscle strength and physical performance in the very old: The Newcastle 85+ Study. Clin Nutr. 2018 Dec 1;37(6):2260–70.
42. Cevenini E, Cotichini R, Stazi MA, Toccaceli V, Palmas MG, Capri M, et al. Health status and 6 years survival of 552 90+ Italian sib-ships recruited within the EU Project GEHA (GEnetics of Healthy Ageing). Age (Omaha). 2014;36(2):949–66.
43. Kamide N, Kamiya R, Nakazono T, Ando M. Reference values for hand grip strength in Japanese community-dwelling elderly: a meta-analysis. Environ Health Prev Med. 2015;20(6):441–6.
44. Seino S, Shinkai S, Fujiwara Y, Obuchi S, Yoshida H, Hirano H, et al. Reference values and age and sex differences in physical performance measures for community-dwelling older Japanese: A pooled analysis of six cohort studies. PLoS One. 2014 Jun 12;9(6):e99487.
45. Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, et al. A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach. Vol. 40,

Age and Ageing. 2011. p. 423–9.
46. Shinkai S, Watanabe S, Kumagai S, Fujiwara Y, Amano H, Yoshida H, et al. Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. Age Ageing. 2000;29(5):441–6.
47. Maruyama H. Motor function and gait in the aged. Rigakuryoho Kagaku. 1999;14(3):101–5.
48. Kuo YL. The influence of chair seat height on the performance of community-dwelling older adults' 30-second chair stand test. Aging Clin Exp Res. 2013;25(3):305–9.
49. Aoyagi K, Ross PD, Nevitt MC, Davis JW, Wasnich RD, Hayashi T, et al. Comparison of performance-based measures among native Japanese, Japanese-Americans in Hawaii and Caucasian women in the United States, ages 65 years and over: A cross-sectional study. BMC Geriatr. 2001;1:1–7.
50. S.Murata, H. Otao, J.Murata, J. Horie, M. Onituka, T. Yokoyama HH. Relationship between the 10-Second Chair Stand Test (Frail CS-10) and Physical Function among the Frail Elderly. Rigakuryoho Kagaku [Internet]. 2010;25(3):431–5. Available from: http://ci.nii.ac.jp/naid/10026929303/
51. Ministry of Health, Labour and Welfare (2015). Overview of Survey of Long-term Care Benefit Expenditures https://www.mhlw.go.jp/toukei/saikin/hw/kaigo/kyufu/14/dl/02.pdf. Accessed 28 Aug 2021.

Figures

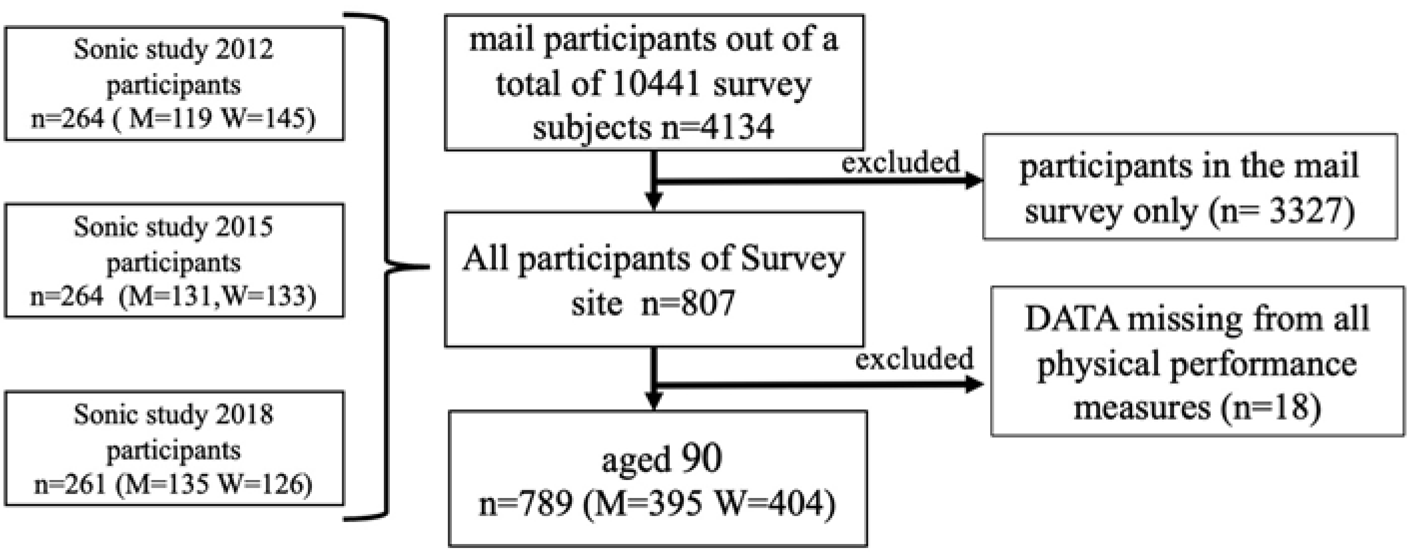

Figure. 1 Flow chart of the review selection process

Figure 1

See image above for figure legend.