J Musculoskelet Neuronal Interact 2009; 9(4):263-267

Hylonome

Original Article

Normative values for maximum power during motor function assessment of jumping among physically active Japanese

A. Tsubaki[1], M. Kubo[1], R. Kobayashi[1], H. Jigami[1], H.E. Takahashi[2]

[1]Department of Physical Therapy and [2]Graduate School of Health and Welfare, Niigata University of Health and Welfare, 1398 Shimami-cho, Kita-ku, Niigata-shi, Niigata, Japan

Abstract

Objectives: To determine the relationship between maximum power relative to body weight (Pmax-rel) and the aging process, and to indicate the target values of improvement of motor function in Japanese individuals. **Methods:** In 410 physically active Japanese subjects (7-79 years) with no impairment of daily activities were performed counter-movement jumps. We evaluated the correlation between age and Pmax-rel, mean Pmax-rel by age group, and the percentage Esslinger Fitness Index score relative to 100% for same-age Europeans (%EFI), by gender. **Results:** Age and Pmax-rel were correlated in both males aged <18 and ≥18 years old (both p<0.01) and females aged <18 and ≥18 years old (both p<0.01). Pmax-rel declined gradually with age, reaching 53.5% of the peak in subjects in their 70s. There was no significant difference in %EFI scores in most age groups. **Conclusion:** Similar to Europeans, Pmax-rel in Japanese individuals is closely correlated with age, declining to 53% of the peak in subjects in their 70s. Thus, Pmax-rel and the %EFI appear to be suitable as normative indices applicable to different human populations for the assessment of physical function.

Keywords: Power, Age, Japanese, Esslinger Fitness Index, Normative Values

Introduction

Physical function changes during the aging process. Such changes are inevitable and affect the entire body. In order to elucidate the changes that take place, heart function[1,2], respiratory function[2], posture control[3], metabolism[4], sensation[5], and cognition[6] are among the various processes that are measured[7].

In addition, the assessment of motor function through jumping movements is not new[8,9]. In the area of sports, using ground force measurements, maximum power relative to body weight (Pmax-rel) has been calculated from the force during a jump, and this is widely used as an indicator of motor function. A recent study examined the reproducibility of Pmax-rel in the elderly[10]. In male and female subjects aged from 19-88 years, they established the high reproducibility of Pmax-rel of a jumping motion, and also reported there was a strong correlation with performance on assessment indices including the Timed Up & Go test, the Chair Rising test, and walking speed. Moreover, Runge et al.[11], in a study of males and females aged 18-88 years, reported changes in muscle mass and jumping Pmax-rel associated with the aging process; there was a high correlation between age and Pmax-rel in both males and females. On the basis of this report and another which targeted males and females under 20 years of age[12], an assessment index called the Esslinger Fitness Index (EFI) was developed. This index is calculated as a percentage of the standard value for each age, which provides helpful feedback and indications of an individual's motor function[13].

However, all of the above-mentioned studies were conducted with European subjects. The literature contains some reports of differences in muscle strength, performance, and power between different ethnic groups[14,15], hence it remains to be established whether the Pmax-rel and EFI results can be applied to Japanese people. In addition, establishing standard Pmax-rel values for the Japanese population by age group will

The authors have no conflict of interest

Corresponding author: Atsuhiro Tsubaki, Department of Physical Therapy, Niigata University of Health and Welfare, 1398 Shimami-cho, Kita-ku, Niigata-shi, Niigata, Japan
E-mail: tsubaki@nuhw.ac.jp

Accepted 26 October 2009

	All (n=410)	Males (n=210)		Females (n=200)	
		<18 (n=47)	≥18 (n=163)	<18(n=44)	≥18 (n=156)
Age (years)	41.3±23.5	10.2±2.3	48.5±19.5	10.6±2.2	51.9±18.2
Height (cm)	157.5±13.1	142.0±14.1	168.1±7.6	144.3±12.6	154.9±6.4
Weight (kg)	53.5±14.0	35.1±10.9	65.0±8.4	36.6±11.5	51.7±6.7
Pmax-rel (W/kg)	40.4±12.2	43.3±9.8	46.0±13.4	41.9±6.3	33.4±8.9

Values are given as means ±SD. <18: under 18 years old; ≥18: more than 18 years old; Pmax-rel: maximum power relative to body weight.

Table 1. Subject characteristics.

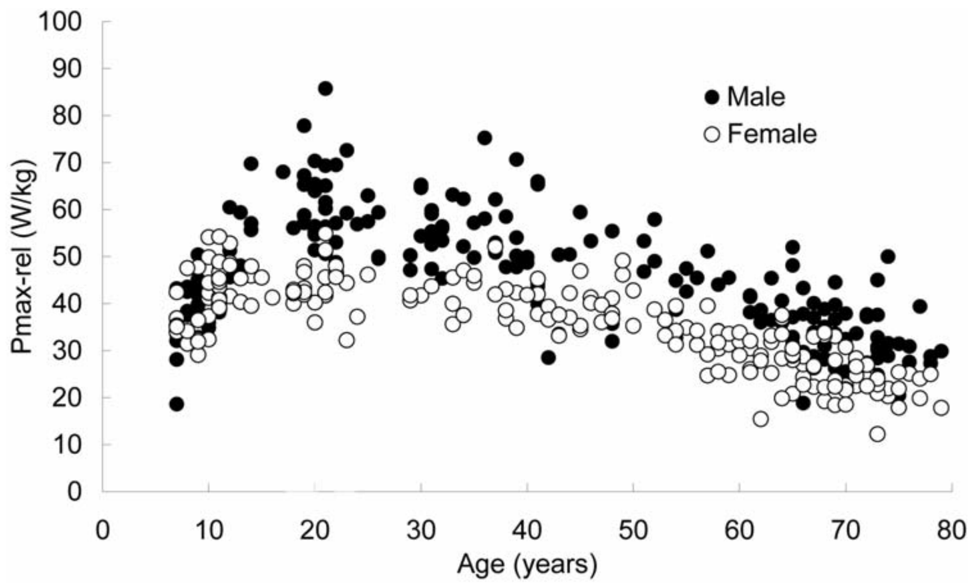

Figure 1. Age-related change in maximum power relative to body weight (Pmax-rel).

provide target values for use in physical therapy with individuals who have ailments and secondary physical impairment due to disease, as well clarify their degree of recovery.

The goals of this study are to determine the relationship between aging and Pmax-rel in healthy physically active Japanese individuals, and to determine standard Pmax-rel values for each decade age group. A further objective is to undertake a comparison of the physical capabilities of Europeans and Japanese people by using EFI scores.

Group	Gender	Age	Height	Weight
<18	males (n=47)	0.79**	0.72**	0.60**
	females (n=44)	0.44**	0.50**	0.30*
≥18	males (n=163)	-0.82**	0.38**	0.16*
	females (n=156)	-0.84**	0.54**	-0.08

*<18: under 18 years old; ≥18: more than 18 years old; *p<0.05; **p<0.01.*

Table 2. Pearson's correlation coefficient of maximum power relative to body weight (Pmax-rel) with age, height and weight.

Materials and methods

Subjects

We recruited healthy residents of Niigata city who responded to an advertisement at a local gymnasium inviting 'physically active healthy people of all ages' to participate in the study. Subjects ranged in age from 7-82 years and none had any impairment of daily activities. The inclusion criteria were: (i) ability to walk at least 800 m unaided; (ii) ability to climb a standard staircase without difficulty; and (iii) ability to perform two-legged jumps[11]. Meanwhile, the subjects who required more than 10 seconds completing the Chair Rising test, were excluded[11]. All subjects provided written consent to participate in the study. The study protocol was approved by the ethics committee of the Niigata University of Health and Welfare.

	Males				Females			
Age (years)	No.	Mean	SD	%Pmax-rel	No.	Mean (%)	SD	%Pmax-rel
0-9	20	37.4	7.2	63.1	13	36.5	5.9	84.2
10-19	33	50.6	10.9	85.5	40	43.9	4.5	101.4
20-29	29	59.2	8.7	100	17	43.3	5.5	100
30-39	29	56.4	7.0	95.2	16	41.9	4.6	96.8
40-49	19	46.5	10.8	78.6	22	39.9	4.2	92.1
50-59	15	44.9	6.8	75.9	22	33.1	4.7	76.4
60-69	36	35.7	6.8	60.3	41	27.9	5.3	64.4
70-79	29	31.7	6.3	53.5	29	23.0	3.7	53.2

%Pmax-rel: calculated relative to 100% for the group aged 20-29 years.

Table 3. Normative value of maximum power relative to body weight (Pmax-rel) by age decade in males and females.

Measurements

All measurements were performed in the gymnasium with subjects wearing light indoor clothes without shoes. Gender, age, and anthropometric characteristics were recorded at the assessment visit.

The subjects performed counter-movement jumps on a portable force platform system (Leonardo Ground Reaction Force Platform, Novotec Medical GmbH, Pforzheim, Germany). The subjects were requested to jump vertically once as high as possible, using both legs. Subjects were allowed to swing their arms freely. An experienced assistant monitored each subject while he or she performed the test in order to prevent injury. Immediately prior to the trials, subjects practiced several times to become accustomed to jumping vertically. Two trials were conducted, with 1-min rest period between each trial. During the trials, the vertical component of the ground reaction force was recorded with a sampling rate of 800 Hz. Velocity was derived from a time series of the ground reaction force[16]. Body mass and starting point of jumping movement were assessed during quiet stance immediately before the jump. Instantaneous power was calculated as the product of force and velocity. In this study, only peak power during the acceleration phase (during concentric contraction of antigravity muscles) was analyzed. Values were selected for analysis from only the trial in which the subject achieved the greatest vertical height. Maximum power values were normalized separately to body weight (Pmax-rel).

Statistical analysis

In order to compare to the previous study[11], we examined the relationship between age and Pmax-rel by Pearson's correlation test in subjects aged under 18 years (<18) and those aged over 18 years old (≥18) by gender. We examined the relationship of height and weight with Pmax-rel, as well. We calculated mean Pmax-rel by age decade, and %Pmax-rel was calculated relative to 100% for the group in their 20s. In addition, we calculated %EFI score, calculated as the percentage EFI score relative to 100% for same-age Europeans[11,12], and then examined the agreement between two populations using a single-sample t-test. Statistical analyses were conducted using SPSS (version 11.0J, SPSS Japan Inc., Japan). A *p* value of <0.05 was considered statistically significant.

Results

From among 419 individuals, aged from 7-82 years, who expressed interest in the study, 6 were excluded because they required more than 10 seconds to complete the Chair Rising test[11] and another 3 subjects aged over 80 years were excluded because there were too few subjects in this age range to constitute this age group. Thus, data obtained from 410 subjects were analyzed in this study. Table 1 shows the participant characteristics.

Age-related change in Pmax-rel is shown in Figure 1. A significant correlation between age and Pmax-rel was found both in males and females. In the <18 group, a correlation between Pmax-rel and other characteristics were significant in males and females, age showed the strong negative correlations with Pmax-rel in ≥18 group (Table 2).

In regards to mean Pmax-rel by age decade, males in their 20s had the highest value, which declined with age. Males in their 70s showed the lowest value of %Pmax-rel at 53.5%. Females aged from 10-19 years had the highest value, which also decreased with age. Similarly to males, females in their 70s showed the lowest value of %Pmax-rel at 53.2% (Table 3).

Table 4 shows the results of comparing %EFI scores by age decade for males and females. Most age groups showed no significant differences in %EFI; the exceptions were male subjects aged 0-9 years (111.2±19.7%; $p<0.05$) and 10-19 years (115.7±15.2%; $p<0.01$) and female subjects aged 10-19 years (105.6±13.7%; $p<0.05$) and 40-49 years (109.7±14.6%; $p<0.01$) who had significantly higher scores, and females aged 70-79 years who had significantly lower scores (92.6±16.7%; $p<0.05$).

Discussion

The three objectives of this study were to clarify the relationship between Pmax-rel and aging in healthy physically active Japanese individuals, to establish the standard Pmax-rel value for each decade age group, and to undertake a comparison of the physical capabilities of Japanese and Europeans by using EFI values. Three important findings were identified. First, in males and females aged over 18 years, Pmax-rel and age show a strong

	Males				Females			
Age (years)	No.	Mean (%)	SD	p value	No.	Mean (%)	SD	p value
0-9	20	111.2	19.7	0.02	13	109.7	18.9	0.088
10-19	33	115.7	15.2	<0.01	40	105.6	13.7	0.014
20-29	29	101.2	15.3	0.954	17	94.8	12.7	0.109
30-39	29	100.5	12.9	0.850	16	105.4	11.7	0.086
40-49	19	92.0	21.1	0.116	22	109.7	14.6	<0.01
50-59	15	102.4	14.5	0.530	22	103.1	12.7	0.264
60-69	36	97.1	17.4	0.289	41	100.1	18.2	0.985
70-79	29	97.8	19.9	0.418	29	92.6	16.7	0.014
p value: for single-sample t-test								

Table 4. %Esslinger Fitness Index (%EFI) score by age decade in males and females.

negative correlation. Second, subjects in their 70s showed roughly a 50% decrease in %Pmax-rel. Finally, no significant difference in %EFI score was seen in most age decade groups.

In regard to previous research into the relationship between jumping Pmax-rel and age, one study undertaken with master athletes over the age of 35[17] revealed a decline in Pmax-rel with age in both males and females. In our study, a similar trend has now been shown for people who are not master athletes. In a study of European males and females aged between 18 and 88 years[11], age and Pmax-rel was found to be significantly correlated (r=-0.86 for males, r=-0.81 for females). In the present study targeting Japanese people, we obtained a similar result for subjects aged over 18 years (r=-0.82 for males, r=-0.84 for females). Given these results, it is plausible that Pmax-rel declines with age irrespective of whether one is a master athlete, and there is no racial difference in this area at least between Europeans and Japanese. In contrast, a different trend was found between males and females aged under 18 in the present study; the strength of correlation between Pmax-rel and age was much weaker in females than in males (r=0.79 for males, r=0.44 for females). This result might be due to difference of time profile in physical maturity between different genders in Japanese population. Japanese females mature much earlier than Japanese males[18,19] and reach their peak maturity in the middle of their 10s. Therefore it is conceivable that the correlation did not manifest strongly in our female subjects aged across the age range from 7 to 18. It is supported by the finding that the mean Pmax-rel value for each decade age group was higher in females aged 10-19 than in those in their 20s. For these reasons, it may be better to make regrouping age ranges differently in Japanese males and females to capture their aging process clearly.

%Pmax-rel for both males and females in their 70s had declined to 53%. Similarly, from power measurements using a cycle ergometer, subjects in their 70s in a previous study showed a decline in Pmax to 56.5% of that of subjects in their 20s[20]. Many studies have shown a decline in muscle strength with age[21-25], as well as in the speed of movement with age[20,26]. Power is the product of force and velocity; thus, the age-related decline of muscle force and muscle velocity means that the decline of their product-power-manifests itself more clearly.

As a result of %EFI scores, significant differences were seen only in males aged 0-9 and 10-19 and in females aged 10-19 and 40-49, whose respective scores were 5.6-15.7% higher than the Europeans. These results might be due to differences of body weight. There are studies indicating that Japanese pre- and post-menarcheal females were smaller and lighter than peers in Caucasian females[27]. Similarly, Japanese adolescent males were lower in height and weight compare to peers in Caucasian males[28]. If actual measurement value of maximum power were similar, lighter one's Pmax-rel became higher because the Pmax-rel was calculated maximum power divided by body weight.

In contrast, our Japanese subjects in their 70s had a lower %EFI score. It might be caused by difference in physical function between different races. One study has shown that elderly Japanese females have lower quadriceps muscle strength than their Caucasian counterparts and also have slower response times[29], and this helps to explain why our Japanese subjects in their 70s had a lower %EFI score.

This study is limited in that as a cross-sectional investigation, it cannot confirm that the decrease in Pmax-rel is truly attributable to the aging process. However, at the same time, the results of this study can serve as a starting point for future longitudinal studies and can be useful in study design.

Following the example of Runge et al.'s study[11], this investigation excluded participants who required more than 10 seconds to complete the Chair Rising test. As a result, only those elderly individuals who excelled in motor function became the subjects of analysis. Therefore, in regard to the mean Pmax-rel levels for each decade age group determined in this study, for the elderly age groups, they reflect the mean of those with superior motor function. These values can be considered goal values for the improvement of motor function in healthy and frail elderly individuals.

Acknowledgements

The authors wish to thank the following individuals for their encouragement and support in subject recruitment: Mr. S Satoh and Mr. Y Okamoto from the incorporated non-profit organization Hapisuka Toyosaka, Dr. Y Nishihara of the Department of Health and Sports for Niigata University of Health and Welfare, Ms. R Tamura of Shitayama Sports Center, Mr. K Kera of Albirex Running Club, and Mr. K Mita of Shibata City Government. The authors also thank Mr. I Konishi for advice on statistical analysis.

Ethical standards

The experiments comply with the current laws of the country in which they were performed.

References

1. Lakatta EG. Age-associated cardiovascular changes in health: impact on cardiovascular disease in older persons. Heart Fail Rev 2002;7:29-49.
2. Rossi A, Ganassini A, Tantucci C, Grassi V. Aging and the respiratory system. Aging (Milano) 1996;8:143-61.
3. Skelton DA. Effects of physical activity on postural stability. Age Ageing 2001;30(Suppl.4):33-9.
4. Betik AC, Hepple RT. Determinants of VO2 max decline with aging: an integrated perspective. Appl Physiol Nutr Metab 2008;33:130-40.
5. Lin YH, Hsieh SC, Chao CC, Chang YC, Hsieh ST. Influence of aging on thermal and vibratory thresholds of quantitative sensory testing. J Peripher Nerv Syst 2005; 10:269-81.
6. Li KZ, Lindenberger U. Relations between aging sensory/sensorimotor and cognitive functions. Neurosci Biobehav Rev 2002;26:777-83.
7. Anstey KJ, Smith GA, Lord S. Test-retest reliability of a battery of sensory motor and physiological measures of aging. Percept Mot Skills 1997;84:831-4.
8. Thorstensson A, Hulten B, von Dobeln W, Karlsson J. Effect of strength training on enzyme activities and fibre characteristics in human skeletal muscle. Acta Physiol Scand 1976;96:392-8.
9. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement jump tests. J Strength Cond Res 2004;18:551-5.
10. Rittweger J, Schiessl H, Felsenberg D, Runge M. Reproducibility of the jumping mechanography as a test of mechanical power output in physically competent adult and elderly subjects. J Am Geriatr Soc 2004;52:128-31.
11. Runge M, Rittweger J, Russo CR, Schiessl H, Felsenberg D. Is muscle power output a key factor in the age-related decline in physical performance? A comparison of muscle cross section, chair-rising test and jumping power. Clin Physiol Funct Imaging 2004;24:335-40.
12. Fricke O, Weidler J, Tutlewski B, Schoenau E. Mechanography - a new device for the assessment of muscle function in pediatrics. Pediatr Res 2006;59:46-9.
13. Ward KA, Das G, Berry JL, Roberts SA, Rawer R, Adams JE, Mughal Z. Vitamin D status and muscle function in post-menarchal adolescent girls. J Clin Endocrinol Metab 2009;94:559-63.
14. Doldo NA, Delmonico MJ, Bailey JA, Hand BD, Kostek MC, Rabon-Stith KM, Menon KS, Conway JM, Carignan CR, Hurley BF. Muscle-power quality: does sex or race affect movement velocity in older adults? J Aging Phys Act 2006;14:411-22.
15. Schiller BC, Casas YG, Tracy BL, DeSouza CA, Seals DR. Age-related declines in knee extensor strength and physical performance in healthy Hispanic and Caucasian women. J Gerontol A Biol Sci Med Sci 2000;55:B563-9.
16. Cavagna GA. Force platforms as ergometers. J Appl Physiol 1975;39:174-9.
17. Michaelis I, Kwiet A, Gast U, Boshof A, Antvorskov T, Jung T, Rittweger J, Felsenberg D. Decline of specific peak jumping power with age in master runners. J Musculoskelet Neuronal Interact 2008;8:64-70.
18. Hermanussen M, Molinari L, Satake T. BMI in Japanese children since 1948: no evidence of a major rise in the prevalence of obesity in Japan. Anthropol Anz 2007; 65:275-83.
19. Sasaki M, Motegi E, Soejima U, Nomura M, Kaneko Y, Shimizu T, Takeuchi F, Yamaguchi T, Yamanaka S, Yamaguchi H. Appraisal of bone maturity age derived from broadband ultrasonic attenuation in Japanese children and adolescents. Bull Tokyo Dent Coll 2003;44:37-42.
20. Kostka T. Quadriceps maximal power and optimal shortening velocity in 335 men aged 23-88 years. Eur J Appl Physiol 2005;95:140-5.
21. Lindle RS, Metter EJ, Lynch NA, Fleg JL, Fozard JL, Tobin J, Roy TA, Hurley BF. Age and gender comparisons of muscle strength in 654 women and men aged 20-93 yr. J Appl Physiol. 1997;83:1581-7.
22. Stoll T, Huber E, Seifert B, Michel BA, Stucki G. Maximal isometric muscle strength: normative values and gender-specific relation to age. Clin Rheumatol 2000;19:105-13.
23. Bohannon RW. Nature of age-related changes in muscle strength of the extremities of women. Percept Mot Skills 1996;83:1155-60.
24. Bohannon RW. Reference values for extremity muscle strength obtained by hand-held dynamometry from adults aged 20 to 79 years. Arch Phys Med Rehabil 1997;78:26-32.
25. Sinaki M, Nwaogwugwu NC, Phillips BE, Mokri MP. Effect of gender, age, and anthropometry on axial and appendicular muscle strength. Am J Phys Med Rehabil 2001;80:330-8.
26. Martin JC, Farrar RP, Wagner BM, Spirduso WW. Maximal power across the lifespan. J Gerontol A Biol Sci Med Sci 2000;55:M311-6.
27. Sampei MA, Novo NF, Juliano Y, Colugnati FA, Sigulem DM. Anthropometry and body composition in ethnic Japanese and Caucasian adolescent girls: considerations on ethnicity and menarche. Int J Obes Relat Metab Disord 2003;27:1114-20.
28. Sampei MA, Novo NF, Juliano Y, Sigulem DM. Anthropometry and body composition in ethnic Japanese and Caucasian adolescent boys. Pediatr Int 2008;50:679-86.
29. Davis JW, Nevitt MC, Wasnich RD, Ross PD. A cross-cultural comparison of neuromuscular performance, functional status, and falls between Japanese and white women. J Gerontol A Biol Sci Med Sci 1999;54:M288-92.