A Comparison of Force and Power Generated in Countermovement Jump between Young and Elderly Subjects

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Abstract

The ageing process in humans is marked by significant decreases in physical performance. The purpose of this study was to compare the parameters derived from a time series of the ground reaction force in a countermovement jump between young and elderly Japanese subjects. We recruited 6 healthy elderly subjects (aged 65-72 years) and 6 healthy university students (aged 20-21 years) in this study and subjected them to a jump test. The force, velocity, height of the center of mass (COM), stored energy, and power were compared between the 2 groups. The maximum velocity, height of the COM, normalized stored energy, and normalized peak power were significantly lower in the elderly subjects than in the young subjects ($p < 0.05$). However, there was no significant difference in the normalized peak force between these groups. In order to improve the performance of the elderly population, it appears necessary to focus not only on force but also on power. Thus, it is important to teach the elderly population the efficient utilization of energy-storing mechanisms.

Introduction

Many studies have reported changes in physical performance related to ageing. For example, it has been widely recognized that muscle strength and muscle mass decline with age (Daley & Spinks, 2000; DiPietro, 2001), and these 2 variables are believed to play a central role in maintaining performance level. However, any movements involved in daily tasks must be performed at a certain speed to be effective. Therefore, to establish a relationship between ageing and physical performance, the speed of movement must be taken into consideration.

Type II muscle fibers, which produce the highest power, exhibit a significant reduction in area due to ageing (Hortobágyi et al. 1995). Therefore, decline in the muscle power output is a key factor in musculoskeletal ageing. Jumping requires a high amount of power. Rittweger, Schiessl, Felsenberg, and Runge (2004) and Runge, Rittweger, Russo, Schiessl, and Felsenberg (2004) have attempted to establish the relationship between ageing and physical performance by using the mechanical power output produced during a countermovement jump (CMJ) as an indicator of physical performance. They reported that the assessment of maximum power appears to have good test-retest reliability and large intersubject variability. They suggested that the power output can be a key factor in the ageing process. As suggested by a previous study (Michaelis et al., 2008), decline in the specific jump power might be observed for Japanese subjects. However, to the best of our knowledge, there are very few reports on the impact of ageing on jump power during CMJ in the Japanese population. The purpose of this study was to

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compare the parameters derived from a time series of the ground reaction force in CMJ between young and elderly Japanese subjects.

Methods

For this study, we recruited 6 healthy elderly people (aged 65-72 years) from a community and 6 healthy university students (aged 20-21 years). Descriptive parameters regarding the subjects' age, number of subjects, gender, height, and body weight are presented in Table 1. The height and body weight of the subjects were matched between both the groups. All subjects provided their written consents for the study.

The subjects performed the CMJ on a Leonardo force platform system (Novotec Medical, Germany). Leonardo mechanography® is a ground reaction force platform attached to a personal computer and an integrated analog-digital board and accompanying software. 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 to prevent injury. Three trials were conducted per session, with 1-min rest periods between each trial. During the trials, we collected the vertical component of the ground reaction force with a sampling rate of 800 Hz. The values of velocity, height of the center of mass (COM), stored energy, and power were derived from a time series of the ground reaction force. Stored energy is defined as energy stored in the muscles of the lower extremities from the beginning of the movement to the instant of the lowest position of the body COM that is utilized during the concentric phase of the CMJ. For analyses, only 1 of the 3 trials, which was performed with the highest force, was selected. The peak power, the peak force, and the stored energy values were normalized separately to the body weight.

Statistical analyses were conducted using SPSS (version 11.0J, SPSS Japan Inc., Japan). Student's unpaired *t* test was used to compare the differences of each component between the 2 groups. A *p* value of <0.05 was considered statistically significant.

Results

The time series of the force, velocity, power, and the height of the COM are shown in Fig. 1 for 1 young and 1 elderly subject performing the CMJ. In this figure, the movement begins at time t0, and the COM is at its lowest position at time t1. The subject lost ground contact at time t2. The period between t0 and t1 is the eccentric phase of knee extension, while the period from t1 to t2 is the concentric phase. After the subject lost ground contact, the body is in air; therefore, the ground

Table 1 Anthropometric measures of the study population.

	Young	Elderly
Age [years]	20.3 ± 0.5 (20-21)	68.0 ± 3.0 (65-72)
Number of subjects (Male/Female)	6 (2/4)	6 (2/4)
Height [m]	1.59 ± 0.08 (1.48-1.70)	1.56 ± 0.06 (1.50-1.64)
Body weight [kg]	53.9 ± 6.8 (45.8-62.5)	56.4 ± 7.1 (45.6-64.9)

*Mean ± S. D. (range)

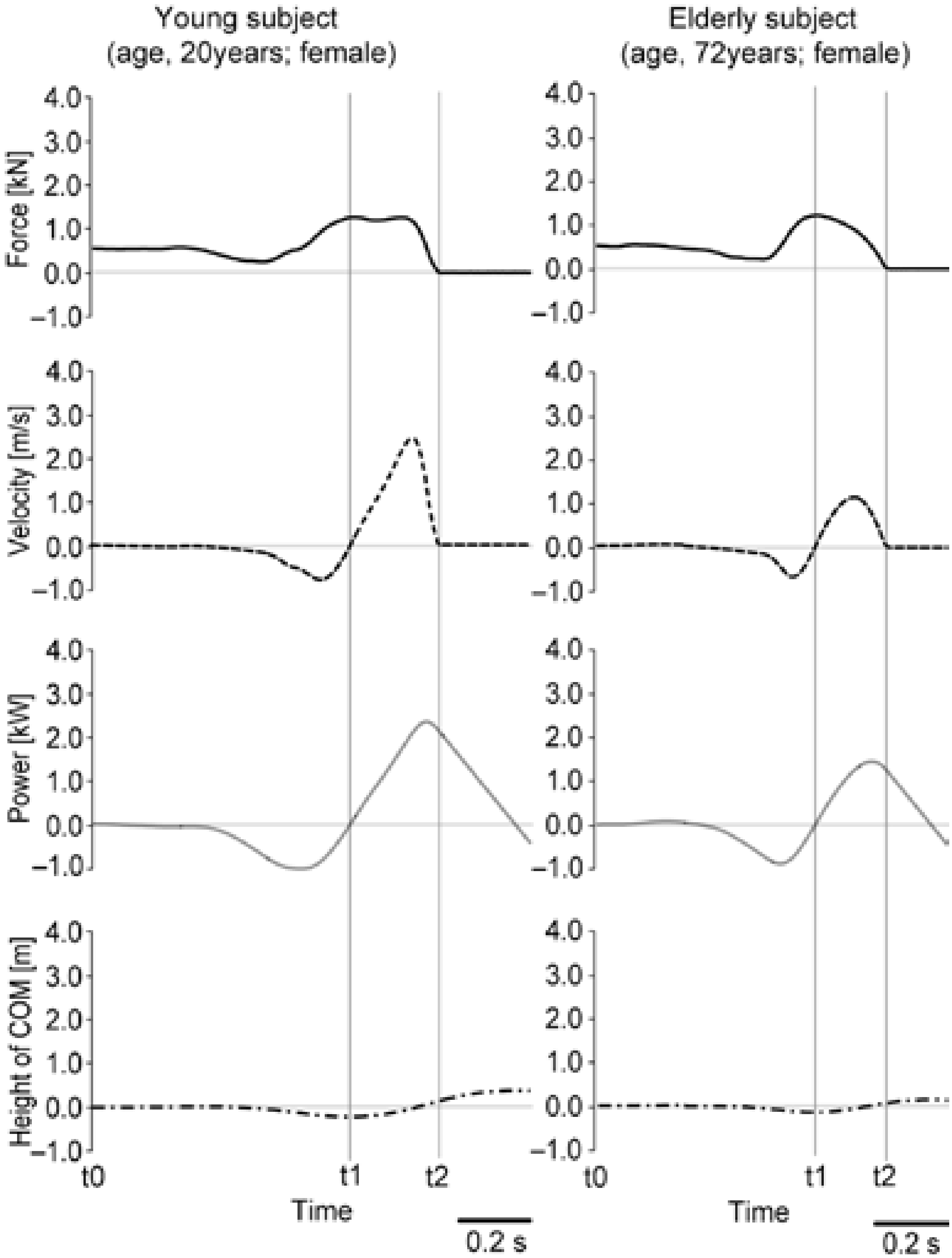

Figure 1. Time series of the force, velocity, power, and the height of the COM in a young (left) and an elderly (right) subject while they performed a CMJ.
t0: the motion was initiated, t1: the COM was at the lowest point, and t2: the subject lost ground contact.

reaction force is equal to zero.

The maximum velocity, height of the COM, stored energy, and peak power were significantly lower in the elderly subjects than in the young students ($p < 0.05$). These parameters decreased by 33.3%, 52.1%, 57.7%, and 46.7%, respectively, in the elderly group, as compared to the corresponding values in the group of young subjects. However, the peak force decreased by only 12.8% in the elderly subjects as compared to the corresponding value in the young subjects; this difference was not significant (Table 2).

Discussion

Several studies have reported the relationship between ageing and physical function. Phillips, Lo, and Mastaglia (2000) reported that muscle force, which was measured with a handheld myometer, declined with age. Bohannon (1997) established that Pearson's correlation coefficient between age and strength of knee extensors ranged from -0.584 to -0.588, and it was found to be statistically significant. In contrast, the peak force did not show any significant change in this study. The discrepancy might have stemmed from the different methods used for measuring the force and the type of muscle contraction. In these studies, force was measured in an open kinetic chain exercise, but in our study, we measured the ground reaction force during a closed kinetic chain movement. The force generated by a closed kinetic chain movement might not decline with ageing.

Martin, Farrar, Wagner, and Spirduso (2000) demonstrated that the power generated from cycling decreased by approximately 7.5% every 10 years after 20 years of age. Kostka (2005) showed that the decline rate of power across the adult life span was 10.7% every 10 years, which was greater than the decrease in the maximal muscle strength. Bean, Leveille, Kiely, Bandinelli, Guralnik, and Ferrucci (2003) reported greater age-associated losses in muscle power than in strength. These studies indicate that peak power is more sensitive than peak force in age-related changes. In this study, the maximum velocity was greater in the young subjects than in the elderly subjects. Power is calculated as the product of force and velocity; therefore, lower velocity indicates lower power.

Liu, Peng, Wei, Chi, Tsai, and Chen (2006) examined the effects of ageing on stored energy in the muscles during the eccentric and concentric phases of CMJ. They reported that less energy was stored in elderly subjects; these results are in agreement with the results of our study.

Table 2 The peak force, maximum velocity, peak power, height of COM, and stored energy data during the CMJ testing for elderly and young subjects.

	Young		Elderly		*p* value
	Mean	S.D.	Mean	S.D.	
Normalized peak force [N/kg]	24.2	3.5	21.1	2.4	0.095
Maximum velocity [m/s]	2.67	0.33	1.78	0.25	0.001*
Normalized peak power [W/kg]	52.3	13.7	27.9	6.2	0.003*
Height of COM [m]	0.48	0.10	0.23	0.09	0.001*
Normalized stored energy [mJ/kg]	67.29	8.27	28.92	11.91	0.001*

*Significant difference ($p < 0.05$).

Cormie, McBride, and McCaulley (2009) performed a curve analysis during the CMJ, and suggested that training status influences not only the peak power but also the shape of the power-time, force-time, and velocity-time curves throughout the CMJ. In this study, 1 subject from each group is shown in Fig. 1. Future studies should clarify the differences in not only the peak values but also the shape of each parameter during CMJ.

There are some limitations in this study. The sample size used in this study was small, and there was no group with middle-aged subjects. In order to support the results obtained in this study and to clarify the effects of ageing, further research on whole generations should be conducted in a cross-sectional study design.

Conclusion

Our findings indicate that stored energy and peak power decline with ageing, while the peak force remains constant. Muscle contraction velocity affects physical performance (Sayers, Guralnik, Thombs, & Fielding, 2005), and the velocity included training is an effective means of enhancing leg power and physical performance (Bean et al., 2004). The performance of the elderly population can be improved not only by increasing the muscle strength but also by increasing the velocity of movement, which can be achieved by teaching the elderly population the efficient utilization of energy-storing mechanisms.

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