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Oral function and vertical jump height among healthy older people in Japan

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Objective: Vertical jump height and oral function affect the general muscle condition. This study aimed to evaluate the association between vertical jump height and oral function among healthy older individuals. ***Basic research design:*** Cross-sectional analytic study. ***Participants:*** 231 independent older people (mean age, 74.4 ± 5.6 years) who participated in the Kyoto Elders Physical Fitness Measurement Research Project. Individuals with partial or complete edentulousness who did not use a prosthetic device or complained of oral/maxillofacial pain were excluded from the study. ***Interventions:*** Grip strength was measured using a Smedley Hand Dynamometer. To measure masticatory performance, the participants were instructed to chew a gummy jelly on their habitual chewing side (left or right) for 20 s. Occlusal force, contact area, and pressure were also assessed. ***Main outcome measures:*** The outcome variable was vertical jump height. The predictor variables were physical status (age, body mass index, and grip strength), oral status (number of present teeth and denture use), and oral function (masticatory performance, occlusal force, occlusal contact area, occlusal pressure, and tongue pressure). These relationships were evaluated with univariate analysis, and then multiple regression analysis was performed with age as the covariate for each male and female participant. ***Results:*** Vertical jump height was significantly associated with grip strength in both men and women. Moreover, in women, it was associated with masticatory performance, occlusal force, and occlusal contact area. ***Conclusions:*** Vertical jump height was closely associated with oral function among healthy older women.

Keywords: *Age, female, older people, occlusal force, vertical jump height*

Introduction

It is important to preserve the general health of older people to maintain and promote their quality of life (Panagioti *et al*., 2018). Moreover, it is crucial to investigate new findings to prevent falls or sarcopenia, because these are key reasons for the decline in the general health of many older people. Previous reports suggest that vertical jump height is a prominent indicator of general health and affects the soleus muscle, which is one of the triceps surae muscles (Akkoc *et al*., 2018). Reinforcement of muscle strength, such as that of the soleus muscle, has been suggested to prevent falls and sarcopenia (Chiu *et al*., 2018).

In contrast, preservation of occlusion or masticatory function in older people is also important in maintaining and promoting general health because oral motor activity can exert strong influences on the motor activity of the major body parts (Mihara *et al*., 2018). Although whole-body skeletal muscle mass decreases with age, the decrease in sarcopenia was closely associated with the decrease in masseter muscle thickness (Umeki *et al*., 2018). Moreover, occlusion was found to be involved in the soleus muscle tone (Mitsuyama *et al*., 2017). Many older people lose their teeth and wear fixed and/or removable dentures on a partially edentulous jaw. The reconstruction of the occlusion with a prosthetic device affects the function of the whole body by activating the temporomandibular joint and skeletal muscles of the whole body (Sforza *et al*., 2006; Moon and Lee, 2011). Based on these findings, it was hypothesized that oral function may affect vertical jump height. However, there have been few detailed reports on the association between vertical jump height and oral function. The aim of this study was to evaluate whether vertical jump height is associated with physical and oral status and oral function in healthy older participants.

Methods

Study design and sample population

A cross-sectional study was conducted with participants of the Kyoto Elders Physical Fitness Measurement Research Project in 2017. This project has been held annually in June for healthcare and sampling of participants. This study was performed in compliance with the Declaration of Helsinki and the guidelines presented in the Strengthening the Reporting of Observational Studies in Epidemiology statement (von Elm *et al*., 2014).

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The study population comprised older male and female individuals who spontaneously visited the school building of the Kyoto Gakuen University for dental examinations on June 24 and 25, 2017. The participants were community-dwelling independent individuals aged more than 65 years. They had maintained occlusion via their own teeth and/or fixed or removable partial dentures. Individuals who complained of oral and maxillofacial pain were excluded from the study. All participants understood the protocols and provided written consent before data collection.

Ethical approval

This study was approved by the Medical Ethics Committee of Kyoto Gakuen University (No. 27-2).

Study variables and data collection

The outcome variable was vertical jump height, assessed using a measuring scale (Jump MD, TKK5106; Takei Scientific Instruments). Each participant performed maximal jumps with countermovement of the lower limbs. Vertical jump height was recorded as the height of the highest jump of three attempts.

The predictor variables included physical status (age, body mass index, grip strength), oral status (number of present teeth, denture use) and oral function (masticatory performance, occlusal force, occlusal contact area, occlusal pressure, and tongue pressure).

Grip strength was measured using a Smedley Hand Dynamometer (Grip-D, TKK5101; Takei Scientific Instruments). Each participant was instructed not to touch any body part with the dynamometer except the hand being measured and to maintain the standard bipedal position during the entire test, with the arm in complete extension. While participants held the dynamometer, the width of the handle was adjusted so that the second phalanx was against the inner stirrup. After brief pauses, two trials were conducted for each hand, alternating between hands. Each participant was asked to exert his or her own maximal grip. Denture use was categorized as 0 = Non-denture wearer and 1 = Denture wearer from a clinical examination using a method similar to that by Masood and colleagues (2017).

To measure masticatory performance, the participants were instructed to chew a gummy jelly on their habitual chewing side (left or right) for 20 seconds. After chewing, they were asked to take 10 mL of distilled water into their mouth and spit the gummy jelly, distilled water and saliva into a filter cup. The concentration of dissolved glucose was then measured to obtain masticatory performance using a glucose measuring device (Glucosensor GS-II, GC).

Occlusal force, contact area, and pressure were assessed based on the following criteria. Participants rested in a chair, with the Frankfort horizontal plane parallel to the horizontal plane, and were instructed to bite a pressure measurement film (Dental Prescale 50H, G) for 3 s with maximum voluntary effort. The occlusal force and contact area were assessed from three readings obtained using an occlusal force measurement system (Occluser 709, GC). Occlusal pressure was calculated by dividing the occlusal force by the occlusal contact area.

Tongue pressure was evaluated by the JMS tongue pressure measurement device, which consisted of a pressure measuring device and a disposable probe (TPM-01, JMS, Hiroshima, Japan). Participants were instructed to hold the probe in place, with a balloon (diameter, 18 mm) as a pressure sensor. They were also instructed to compress the balloon onto their palate for 7 s with maximum voluntary effort. The average of three measurements was used for the analysis.

Data analysis

To compare each variable against vertical jump height among gender groups, we used Spearman's rank correlation coefficients. The associations between the predictor and outcome variables were determined by multiple regression analysis, with age as a covariate. Analyses were conducted using BellCurve for Excel (Social Survey Research Information Co, Ltd., Tokyo, Japan). The statistical significance level was set at $p < 0.05$.

Results

The study population comprised 52 men and 179 women with a mean age of 74.4 ± 5.6 years (range 65–89 years). Table 1 describes measures of vertical jump height, physical status, oral status and oral function among participants. The Spearman's rank correlation coefficients between the outcome variable and all predictor variables are shown in Table 2. Among male participants age, grip strength, occlusal force, and occlusal contact area were correlated with vertical jump height ($p < 0.05$). Multiple regression analysis with age as a covariate revealed a significant relationship between vertical jump height and grip strength ($p < 0.05$) (Table 3). In contrast, among female participants age, grip strength, number of present teeth, occlusal force, and occlusal contact area were significantly correlated with vertical jump height ($p < 0.05$) in rank correlations. Multiple regression analysis with age as a covariate revealed vertical jump height to be predicted by grip strength, masticatory performance, occlusal force, and occlusal contact area ($p < 0.05$) (Table 3).

Discussion

The present findings demonstrate that vertical jump height is significantly associated with grip strength in both men and women and with greater masticatory performance, occlusal force, and occlusal contact area only in women.

Vertical jump height involves jumping vertically on the spot using both feet, without running from an upright posture. It corresponds to muscular strength and instantaneous power among physical strength elements (Kimura *et al*., 2012). The motor function and physical fitness of humans decrease with age (Nakagaichi *et al*., 2018), and vertical jump height and grip strength have also been reported to decrease with age (Lockie *et al*., 2017; Lin *et al*., 2019). Healthy elderly people cannot avoid muscle weakness and decreases in muscle mass with age, and reduction in grip strength is a factor in sarcopenia (Cruz-Jentoft *et al*., 2010; Yoshimura Y *et al*., 2018). The results of this study revealed that vertical jump height was positively associated with grip strength in both healthy men and women. Moreover, vertical jump height may also be an indicator of sarcopenia in addition to grip strength, which is currently a measure of sarcopenia.

Table 1. Distribution of independent and outcome variables among 231 older adults

	Total (n=231) *Mean ± SD or n (%)*	*Males (n=52)* *Mean ± SD or n (%)*	*Females (n=179)* *Mean ± SD or n (%)*
Age (yr)	74.4 ± 5.6	77.0 ± 5.3	74.1 ± 4.8
Body-mass index	21.7 ± 2.5	22.6 ± 2.7	21.4 ± 2.5
Grip strength (kg)	24.0 ± 6.3	33.0 ± 5.6	21.5 ± 3.6
Vertical jump height (cm)	23.0 ± 7.3	27.8 ± 7.5	21.3 ± 6.4
Number of present teeth	22.9 ± 7.2	22.4 ± 8.8	23.0 ± 6.7
Denture usage, *n* (%)	89 (36.9)	23 (44.2)	66 (36.9)
Masticatory performance (mg/dL)	171.1 ± 54.9	180.0 ± 58.9	170.0 ± 55.3
Occlusal force (N)	474.5 ± 280.9	593.0 ± 373.7	445.0 ± 245.0
Occlusal contact area (mm^2)	13.3 ± 8.6	16.7 ± 12.0	12.5 ± 7.4
Occlusal pressure (N/mm^2)	37.4 ± 7.6	37.3 ± 7.2	37.4 ± 7.8
Tongue pressure (kPa)	31.0 ± 6.4	31.8 ± 6.4	30.7 ± 6.4

SD = Standard Deviation

Table 2. Rank correlations between predictor variables and vertical jump height

Variable Name	*Vertical jump height*			
	Males (n=52)		*Females (n=179)*	
	rs	*p*	*rs*	*p*
Age	-0.669	<0.001**	-0.363	<0.001**
Body-mass index	0.053	0.712	-0.040	0.600
Grip strength	0.603	<0.001**	0.432	<0.001**
Number of present teeth	0.209	0.138	0.191	0.010*
Denture usage	-0.198	0.160	-0.152	0.043*
Masticatory performance	0.191	0.174	0.147	0.050*
Occlusal force	0.297	0.032*	0.230	0.002**
Occlusal contact area	0.290	0.037*	0.202	0.007**
Occlusal pressure	-0.036	0.803	0.021	0.780
Tongue pressure	-0.249	0.075	0.097	0.197

rs = Spearman's rank correlation
* P<0.05, ** P<0.01, Spearman rank correlation coefficient test

Table 3. Multiple regression analyses for predictors of vertical jump height in men and women, with age as a covariate

Variable Name	*Vertical jump height*					
	Males (N=52)			*Females (N=179)*		
	F	*t*	*p*	*F*	*t*	*p*
Grip strength	12.949	3.599	<0.001**	22.854	4.781	<0.001**
Number of present teeth	-	-	-	1.371	1.171	0.243
Denture usage	-	-	-	0.832	-0.912	0.363
Masticatory performance	-	-	-	5.525	2.350	0.020*
Occlusal force	0.429	-0.655	0.516	9.682	3.112	<0.001**
Occlusal contact area	0.661	-0.813	0.420	9.750	3.122	<0.001**

* p<0.05, ** p<0.01.
F: F statistic, t: t-statistic

Although there was no association between vertical jump height and occlusal force and contact area in men, there were positive associations with occlusal force and contact area in women. Participants were limited to those with an occlusion involving natural teeth and/or fixed or removable partial dentures, because occlusal loss can affect physical function. Vertical jump height and occlusal force are both indicators of muscle mass and instantaneous power (Pandy and Zajac, 1991; Mihara *et al*., 2018). Additionally, occlusal contact is necessary for attitude control and improved concentration in performing a vertical jump involving instantaneous power (Kobayashi *et al*., 1996). Furthermore, occlusal force is related to the structure and function of the cervical region and the upper trunk and affects the physical abilities of the individuals (Rues *et al*., 2011). Moreover, preservation of occlusal contact strengthens leg and/or grip strength (Yamaga *et al*., 2002). Conversely, loss of occlusal contact increases the risk of falls from adverse effects on muscular strength and reduced ability to maintain equilibrium (Okuyama *et al*., 2011). Moreover, the vertical jump height controlled by muscle strength and posture may be related to both occlusal force with muscular strength and occlusal contact area with equilibrium sensation. It is also clear

that vertical jump height and occlusal force are related to the risk of transition to long-term care (Kono, 2009; Masaki *et al*., 2018). Based on these reports, occlusal force and contact area, as well as vertical jump height, may be indicative of sarcopenia. However, the gender differences have been reported previously: occlusal force in women showed a gradual decline with age, whereas a decline was more prominent in older men (Kono, 2009). Decreased muscle mass and strength is more noticeable in men (Hurley *et al*., 1995). Therefore, in this study, sex differences in occlusal force may be due to the relatively slow decrease in muscular strength in women compared with men until the age of 70 years. Moreover, the decrease in muscle mass related to vertical jump height and/or occlusal force in older men is greater than that in older women, suggesting a sex difference. This difference may explain why vertical jump height was associated with occlusal force in women, but not in men. Likewise, vertical jump height was also associated with occlusal contact area only in women. This result may be supported by a study that reported that occlusal contact area is positively correlated with occlusal force (Kitafusa, 2004).

Similarly, vertical jump height was positively associated with masticatory performance only in women. It has been reported that masticatory performance is also related to muscular strength and instantaneous power (Gaszynska *et al*., 2017). Moreover, motor deterioration of the masseter muscle and central neural dysfunction with aging leads to a decrease in masticatory performance due to reduction in mandibular motion (Chen *et al*., 2015; Ikebe *et al*., 2011). This is noticeable in patients with senile dementia and those with oral dyskinesia related to long-term administration of antiparkinsonian drugs (Campos *et al*., 2017; Ribeiro *et al*., 2017). Additionally, masticatory performance is related to occlusal force (Ikebe *et al*., 2011). Increase of motor function and rapid reaction of the central nervous system may improve vertical jump height in people with high occlusal force, occlusal contact area, and masticatory performance, because participants with low occlusal force and occlusal contact area tended to have low masticatory performance in this study. Furthermore, as with the occlusion function, masticatory performance was related to vertical jump height only in women. This may be the result of mild muscle weakness, as well as occlusal function, in women compared to men. However, this finding may have been affected by the higher mean age for men and the recruitment of fewer male than female participants.

Limitations

This study has some limitations. As we have seen, more women than men participated. Had the number of men and women been equal, it may not have been necessary to analyse the two gender groups independently. We recommend that future studies should further evaluate these relationships in men.

Conclusion

Vertical jump height was associated with grip strength in both men and women and with greater masticatory performance, occlusal force, and occlusal contact area in women. Vertical jump height may be associated with oral function in healthy older women.

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