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Reliability, Sex, and Direction Differences in the New Balance Ability Test for Middle-aged and Older People

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Abstract

This study aimed to examine the reliability of a new test that evaluates differences in balance ability, sex, and evaluation parameters when moving in the back/forth or left/right direction, as well as contact times, total contact time, and their relations during an unstable standing posture in middle-aged and older people. The participants were 31 Japanese individuals (17 men: mean age, 61.8 years; standard deviation (SD) = 8.3; 14 women: mean age, 56.9 years; SD = 9.6). They were instructed to maintain a stable standing posture for 1 minute on the plate of the new device without contacting the edge of a contact-sensing plate. This device leans the plate either back/forth or left/right when standing on the plate and can measure times and their time of contact with the plate edge. The test was performed twice with a 1-minute interval after one practice trial in either condition (back/forth or left/right direction). The time per contact (total contact time/contact times) was used as an evaluation parameter. Insignificant differences were found between trials in evaluation parameters, contact times, and total contact time in both back/forth and left/right directions. Intraclass correlation coefficients (ICC) were ≥0.7 in both directions. A two-way analysis of variance showed insignificant interaction or main effects of sex and direction conditions for the evaluation parameter and the total contact time. Although no significant interaction was found for contact times, a significant main effect was found for sex. The post hoc test showed that men had higher values and larger effect sizes (Cohen's d back/forth: 1.21, left/right: 1.27) than women in both back/forth and left/right directions. A correlation analysis showed relatively high correlations between back/forth and left/right direction evaluation parameters in both sexes (Men: r = 0.71, Women: r = 0.80). In conclusion, this new balance ability test has a high reliability in middle-aged and older people, and the evaluation parameter does not indicate sex differences or differences in the amount of back/forth and left/right movement. The relations between the parameters of back/forth and left/right directions are high in both sexes.

Keywords

Dynamic balance, standing, contact-sensing plate, back/forth, left/right direction

1. Introduction

Human physical functions decrease with age. Individuals, in the senile state often find it difficult to walk and also fall easily when triggered by frail and sarcopenia. Falls in older individuals likely require nursing care [1-3]. In Japan, a super-aging society, all kinds of efforts have been conducted to extend the health life. In particular, training for fall avoidance is widely conducted in the elderly, as supported by numerous studies on fall prevention [4-10]. Particularly, the Japanese Orthopaedic Association recommends locomotion training for muscle-strength improvement and fall prevention [11-13].

The causes of falls in the elderly are divided into passive and active events. The former is when they are hit by another person or due to hard braking while standing in the tram or on a bus. The latter corresponds to a stumble when standing from a sitting position, tripping when walking, or falling when going up and down the stairs. In particular, the elderly have a high risk of stumbling even with a slight slope or undulation. For instance, when there is a level difference between the entrance or rooms, slippery floor, or in the bathroom the falls are thus not limited to the outdoors. To avoid a fall, the elderly need to be able to maintain a stable posture (to exert a balance ability) when their standing position is disturbed for whatever reason.

Balance is the ability to maintain a stable standing posture (active ability) by one's loading stimulation such as one-leg standing and physical movement, and the ability to maintain or manipulate a support base (passive ability) against external loading stimulation (stepping according to stimulation, standing on unstable board). One-leg standing with eyes open, functional reach test (FRT), and the timed up & go (TUG) are the formers' typical and widely used tests to date. More recently, the balance board test, which manipulates a support base against a disturbance and keeps a stable standing posture, has been developed as a passive test. The balance board test has significant correlations with leg strength, the Berg balance scale (BBS), FRT, and TUG, but these correlations are not high, enough to reflect a different ability [14-18]. The support base of the balance board can move in every direction including left/right or back/forth because the reverse side of the plate has only one boss on the center. Hence, the balance board itself is very unstable. To maintain a stable posture on the board, subjects are required to both apply instantaneous adaptability and balance for manipulating the board. To appropriately evaluate the elderly's balance ability, it is important to evaluate the balance ability during an unstable standing posture in addition to the usual balance ability during stable standing. However, in the elderly, the balance board test using such a board that moves largely in every direction can result in falls.

Thus, considering safety, we developed a new device in which the plate leans slightly either left/right or back/forth (Takei, Tokyo, Japan). This device can measure times and their time which the plate-edge contacted to a contact-sensing plate. This study aimed to examine the reliability of the new balance ability test, differences in sex and evaluation parameters when moving in the left/right or back/forth direction as well as contact times, total contact time, and their relations in middle-aged and older people.

2. Methods

2.1 Participants

Participants included 31 middle-aged and older people (17 men, 14 women) undergoing an exercise course of 90 min per week. They were confirmed not to have any disease of the legs and back in the preliminary research. This study was approved by the research ethics committee of the higher education thrust mechanism, Osaka Prefectural University (2018-2022).

2.2 The measuring device

The plate of the measuring device has four built-in load sensors. The signals from the plate, contact-sensing plate, and step mat are sent to a personal computer through a repeater (A/D converter) and recorded. The plate size was 300 mm2 and 72 mm in height. The range of angle variation was ±2.5º either in the left/right or back/forth direction. Details of their hardware are described in Table 1. The typical balance (DYJOC) board measures the angle variation of the plate from a horizontal condition to a maximal angle. On the other hand, the present device measures times and the time at which the plate-edge contacts a contact-sensing plate; not angle variation. The contact times, total contact time, and angle rate can be calculated using software on a personal computer (Windows 10®, ≥ 32-bit). The measuring time is 1–600 s, and the sampling frequencies can be 10, 20, 50, or 100 Hz. Figures 1 and 2 show the front and reverse sides of the plate, which were designed to move left/right or back/forth by a three-boss set on the center of the reverse side of the plate.

Table 1. Hardware in the new balance measurement system

Style	Weight	Size	Quantity
Plate	11.1 kg	300(W) × 300(D) × 72(H)mm	1
Contact-sensing plate	0.1 kg	100(W) × 300(D) × 5(H)mm	2
Step mat	0.1 kg	100(W) × 300(D) × 5(H)mm	2
Repeater	4.3 kg	430(W) × 270(D) × 60(H)mm	1
Horizontal block	2.1 kg	300(W)	2

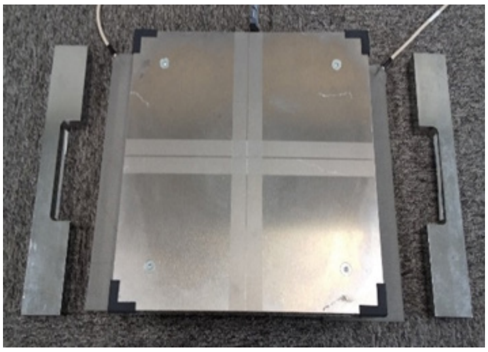

Figure 1. Surface of plate and blocks.

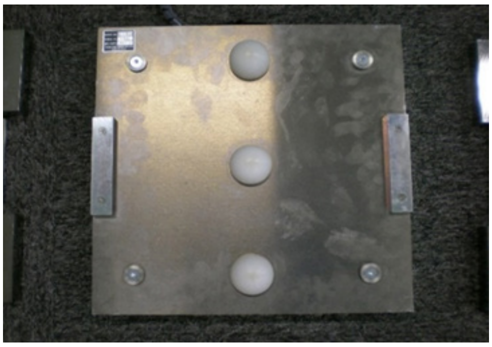

Figure 2. Reverse side of the plate.

2.3 Measurement of new balance ability

The participants stood on the plate of the measurement device (Fig. 3) which can slightly lean to the Y-axis (back/forth) or X-axis (left/right) direction (Figs. 4 and 5). Then, participants were instructed to maintain a stable standing posture for 1 minute without letting the edge contact a contact-sensing plate. During a measurement, they maintained an open-leg standing position wherein the toes of both legs were aligned to the plate edge and their hands on their hips.

After the tester confirmed a stable posture on the plate, the measurement started. When the plate edges contacted a contact-sensing plate, the participants were notified by a buzzer, and their contact times were measured simultaneously. Their times and contact time were measured for 1 min. Right after the buzzer, the participants had to try to quickly remove the plate edge from the contact-sensing plate. To avoid a fall during the measurement, we deployed spotters on both sides. No participants dropped from the plate or fell during the measurement.

The test was performed randomly twice with a 1-min interval after one practice trial under a changing condition in only the back-forth (Fig. 4) or left-right (Fig. 5) direction. The data were recorded at a sampling frequency of 50 Hz.

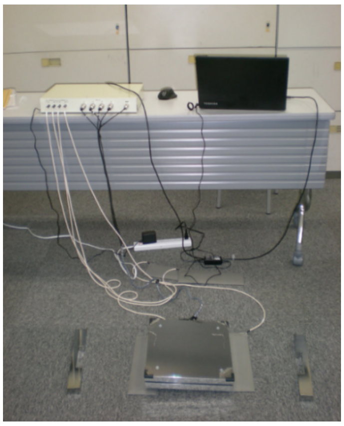

Figure 3. The new balance measurement device.

Figure 4. Dynamic balance measurement in the back/forth direction.

Figure 5. Dynamic balance measurement in the left/right direction.

2.4 Contact times, total contact time, and evaluation parameters

In this study, we computed the contact times and the total contact time in the back/forth and left/right directions for 1 minute. The time per contact was used as an evaluation parameter.

2.5 Statistical analysis

Data were analyzed using SPSS software version 23.0 for Windows (SPSS Inc., Tokyo, Japan). Descriptive statistics were reported as mean ± standard deviation. Student's t-tests were used to examine sex differences in age, height, weight, and BMI in participants (sample). The size of the mean differences, that is the effect size, was examined by Cohen's d. Cohen's d ≤0.2 is considered small, ≥0.5 moderate, and ≥0.8 large [19]. Z-tests were used to examine the differences between the mean height and weight in the sample and in the national median, that is contemporary norms [20]. Trial-to-trial reliability was determined using an intraclass correlation coefficient (ICC). ICC >0.7 is considered as good [21]. The ICC degree was determined based on ICC decision criteria. A repeated measure two-way ANOVA was used to examine the significance of differences among each evaluation parameter measured in the left/right or back/forth directions according to sex and the effect size was calculated by $\eta 2$. In this study, an $\eta 2$ ≤0.01 was considered small, ≥0.06 as moderate, and ≥0.14 as large [22]. Multiple comparison tests were conducted using the Bonferroni method. A p-value <0.05 was considered statistically significant.

3. Results

3.1 Age and physical characteristics (height, weight, and BMI) of participants

Table 2 shows the basic statistics of age, height, weight, and BMI according to the participants' sex. No significant sex differences were found in age. Height and weight were significantly higher in men than in women. In addition, the height and weight were similar to those of contemporary controls [20] in both sexes. Participants in this study were considered to be middle-aged and older people with normal physiques.

Table 2. Mean and standard deviations of age, height, weight, and BMI according to sex

	Men (N=17)		Women (N=14)		t	p	Cohen's d
	M	SD	M	SD			
Age (year)	61.8	8.3	56.9	9.6	1.525	0.138	0.57
Height (cm)	168.1	7.2	158.3	4.6	4.395	0.000*	1.64
Weight (kg)	67.5	11.3	52.5	6.1	4.727	0.000*	1.67
BMI	23.8	3.0	21.0	2.6	2.793	0.009*	1.04

Note. *: p<0.05

3.2 Trial-to-trial reliability of evaluation parameters, contact times, and total contact time

Table 3 shows the basic statistics of two trials for the evaluation parameters, contact times, and total contact time measured in the back/forth or left/right direction and the mean differences and ICC. No significant differences were observed between trials in evaluation parameters, contact times, and total contact time in any direction, and the effect size (Cohen's d) was ≤0.2. The ICCs of evaluation parameters were 0.70 for the back/forth, 0.92 for the left/right direction, and 0.89 for the total back/forth and left/right directions. The mean of the two trials was henceforth used as a representative value. In addition, the ICC for contact times and total contact time was 0.76-0.87 for the back/forth and left/right directions.

3.3 Sex and direction differences in evaluation parameter, contact times, and total contact time

Table 4 shows the results of a two-way ANOVA on evaluation parameters, contact times, and total contact time according to sex and direction. Although the means in men were larger than those in women for all variables, the ANOVA showed no significant interaction or main effects of sex and direction for the evaluation parameter and total contact time. Although no significant interaction was found for contact times, there was a significant main effect of sex. The post-hoc test corroborated the higher values of men in both back/forth and left/right directions, as well as a large effect size (Cohen's d) (back/forth: 1.21, left/right: 1.27).

Table 3. Trial-to-trial reliability and mean differences among trials (n = 31)

	1st time		2nd times					
	M	SD	M	SD	t	p	Cohen's d	ICC
Evaluation parameter (Time per contact)								
Back-forth direction	0.38	0.11	0.37	0.10	0.75	0.46	0.11	0.70
Left-right direction	0.35	0.11	0.36	0.11	1.20	0.24	0.08	0.92
Back-forth + left-right directions	0.73	0.21	0.73	0.20	0.12	0.91	0.01	0.89
Contact-times								
Back-forth direction	56.5	12.38	58.1	12.89	1.01	0.32	0.13	0.76
Left-right direction	55.5	13.31	56.6	13.62	0.72	0.48	0.08	0.80
Total contact-time								
Back-forth direction	21.4	6.90	21.0	5.93	0.48	0.63	0.06	0.80
Left-right direction	19.1	6.00	20.0	6.36	1.61	0.12	0.15	0.87

Notes. M: Means, SD: standard deviation, t: t-value, ICC: intraclass correlation coefficient.

Table 4. Results of two-way analysis of variance for evaluation parameters, contact times, and total contact time (n = 31)

	Back/forth direction		Left/right direction							
	M	SD	M	SD		F	p		η^2	Post-hoc
Evaluation parameter (Time per contact)										
Men	0.36	0.11	0.34	0.10	F1	1.31	0.26		0.04	
Women	0.40	0.09	0.38	0.13	F2	1.91	0.18		0.06	
					IN	0.00	0.97		0.00	
Contact-times										
Men	63.1	8.45	62.4	9.66	F1	15.93	0.00	*	0.36	Back/forth: Men > Women
Women	50.3	11.88	48.3	11.99	F2	0.59	0.45		0.02	Left/right: Men > Women
					IN	0.16	0.69		0.01	
Total contact-time										
Men	22.0	5.64	20.5	4.43	F1	0.94	0.34		0.03	
Women	20.1	6.64	18.5	7.50	F2	3.32	0.08		0.10	
					IN	0.00	0.98		0.00	

Notes. M: mean, SD: standard deviation, F: F-value, F1: main effect of sex, F2: main effect of direction, IN: interaction.

3.4 Correlation coefficients among age, physique, evaluation parameters, contact times, and total contact time of back/forth and left/right directions according to sex

Table 5 shows the correlation coefficients among age, physique, evaluation parameters, contact times, and total contact time in the back/forth and left/right direction according to sex. Relative high correlations were found between back/forth and left/right direction evaluation parameters in both sexes (Men: r = 0.71, Women: r = 0.80). In men, the evaluation parameter in the back/forth direction showed relatively high correlations with the total contact time (r = 0.66-0.90), and the evaluation parameter in the left/right direction showed relatively high correlations with the total contact time (r = 0.66-0.81) and contact-times (r = −0.66). Further, moderate correlations were found for the total contact time (r = 0.69) and contact times (r = 0.56) between the back/forth and left/right directions. In women, the evaluation parameter in the back/forth direction showed relatively high correlations with the total contact time (r = 0.75-0.81), and the evaluation parameter in the left/right direction showed a relatively high correlation with the total contact time (r = 0.88). Moderate correlations were found between the contact times in the left/right direction and the total contact time in both directions (r = 0.55, r = 0.62) as well as for the total contact time (r = 0.69) and the contact time (r = 0.62) between both directions. In addition, there was a moderate correlation between height and the total contact time in the left/right direction for men (r = 0.51).

Table 5. Correlations among age, physique, evaluation parameters, contact times, and total contact time in the back/forth and left/right directions according to sex (n = 31)

	1	2	3	4	5	6	7	8	9	10
1. Age		0.38	-0.03	-0.21	0.28	0.29	0.25	0.06	0.35	0.33
2. Height	-0.44		0.16	-0.31	0.19	0.09	0.18	-0.29	0.22	0.00
3. Body weight	-0.74 *	0.70 *		0.89 *	-0.09	-0.04	0.06	-0.02	-0.03	-0.02
4. BMI	-0.71 *	0.25	0.86 *		-0.16	-0.08	0.00	0.14	-0.11	0.00
5. Estimation parameter (Time per contact) (back/forth)	-0.32	0.44	0.51 *	0.39		0.80 *	0.26	0.24	0.81 *	0.75 *
6. Estimation parameter (Time per contact) (left/right)	0.06	0.40	0.23	0.04	0.71 *		0.03	0.19	0.52	0.88 *
7. Contact-times (back/forth)	0.31	-0.29	-0.34	-0.27	-0.43	-0.43		0.62 *	0.78 *	0.33
8. Contact-times (left/right)	0.06	-0.11	-0.05	-0.01	-0.38	-0.66 *	0.56 *		0.55 *	0.62 *
9. Total contact-time (back/forth)	-0.23	0.40	0.44	0.31	0.90 *	0.60 *	-0.01	-0.16		0.69 *
10. Total contact-time (left/right)	0.10	0.51 *	0.32	0.08	0.66 *	0.81 *	-0.17	-0.12	0.69 *	

Notes. *: $p < 0.05$, The left-lower values show correlation coefficients in men, and the right-upper values show those in women.

4. Discussion

In this balance board test using our newly developed device, the shorter times at which the plate-edge contacted a contact-sensing plate, and the shorter time, indicate a higher balance ability. This study used time per contact as an evaluation parameter to examine trial-to-trial reliability, differences due to sex and direction, and their relationship with the contact times and the total contact time in the new test which evaluates balance ability during an unstable standing posture.

Demura et al. [23] examined the reliability of center foot pressure shaking during a static standing posture based on the ICC. Since a significant difference was found between the first and following trials, they examined differences between trials and ICC leaving out the first trial. They reported that most variables did not show differences among trials and had a high reliability. Similarly, this study examined the ICC of the evaluation parameter (time per contact) based on two trials performed after a single practice trial. According to the results of this study, no significant differences were found between trials in evaluation parameters, contact times, and total contact time, being consistent with Demura et al.'s study.

The ICCs of the evaluation parameter in the back/forth and left/right directions were 0.70 and 0.92, respectively. The ICC of the total back/forth and left/right directions was 0.89. In addition, the ICCs of the contact times and the total contact time were >0.76. Based on a standard ICC ≥0.7 for every variable in both directions, the trial-to-trial reliability of the new balance ability test is demonstrated.

The ICC of the evaluation parameter was higher in the left/right (0.92) direction than in the back/forth (0.70); thus, the reliabilities differ. In Demura et al. [23], a static standing posture was maintained on a stable plate, it is unlikely that the habituation to measure affects the measurements. However, in this study, operating an unstable plate was required to maintain a stable standing posture. As the center of gravity varies in back/forth movement compared to left/right movement while standing [24], maintaining stability on an unstable plate in the back/forth direction is difficult, resulting in large individual differences. That is, it is possible that the difficulty level of the movement involved in the postural maintenance influences the measurements. To obtain more stable data, it is necessary to take the ingenuity of a practice trial or the number of test trials.

Thus, the high reliability in the evaluation parameter, contact times, and total contact time (0.70-0.92), makes it possible to evaluate balance using any one of them.

No significant differences were found in the back/forth and left/right directions for the evaluation parameter, contact times, and total contact time. Therefore, no direction differences were observed with the new balance ability test. Reliable results could be hence obtained in any direction. Ogaya et al. [25] examined the postural control in young and older people using a DYJOC board and reported no significant difference in the back/forth angle fluctuation range for 20 s; however, the total angle fluctuation index was significantly larger in young people. This could be because despite the similar degree of shaking in young and older people, older people try not to move in the DYJOC board while young people control a posture by constantly moving the board. In the present study, the contact times and total contact were short, as was the time per contact in both directions; no difference was observed because subjects were instructed not to contact a contact-sensing plate under both back/forth and left/right direction, and to separate the plate-edge from the contact-sensing plate after contact as fast as possible.

As the test used in this study differs from that using the DYJOC board, and the range of angle fluctuation is ±2.5º in both back/forth and left-right directions, the subject can easily separate the plate-edge from a contact-sensing plate, and it was considered that the difference was not seen.

Although the means of men were larger for the evaluation parameter, contact times, and total contact time, a significant sex difference was found only for contact times: men had larger values in both back/forth and left-right directions (Effect size: 1.21 and 1.27). However, men were also long in the contact time, hence, it is inferred that an insignificant difference was found in the evaluation parameter which divided the total contact time by the contact times (the time per one contact).

Thus, no differences in back/forth and left/right directions or sex were observed in the time per contact, being considered appropriate as an evaluation parameter of the new test.

Relative high correlations were observed between evaluation parameters in both directions and both sexes (Men: $r = 0.71$, Women: $r = 0.80$). That is, balance ability can be evaluated by the evaluation parameter in the back/forth or left/right direction for both sexes.

The contact times in the left/right direction showed moderate correlations with those in the back/forth direction in both sexes (Men: $r = 0.56$, Women: $r = 0.62$), but in men, it showed significant correlations with height ($r = 0.51$) and the evaluation parameter in the left/right direction ($r = -0.66$), and in women, with the total contact-time of left/right ($r = 0.62$) and back/forth ($r = 0.55$) directions. That is, it is considered that the contact-times relation with height and the time per one contact in men, and with the total contact-time of back/forth and left/right directions in women. In addition, although leg strength was not measured, the body-site strategy to gain stabilization differs between back/forth and left/right directions in the balance board test wherein the base of support is unstable like in the present study [26-28]. Fujiwara et al. [29] and Shiota et al. [30] reported that physique, muscular strength, etc. also have an effect; physique and muscular strength are usually higher in men.

The participants in the present study were middle-aged and older people undergoing an exercise course of 90 min per week; thus, an active group. Further studies with more trials and larger sample sizes, as well as a comparison with young people on the time per contact, are necessary to examine reliability, sex, and direction differences when applying the new test.

5. Conclusion

In conclusion, we observed high trial-to-trial reliability in the new balance ability test for middle-aged and older people in the evaluation parameter (time per contact), contact times, and total contact time, but no sex and direction differences in the evaluation parameter. The correlations between the parameters of back/forth and left/right directions are high in both sexes.

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References

[1] Gusi, N., Adsuar, J. C., Corzo, H., del Pozo-Cruz, B., Olivares, P. R., & Parraca, J. A. (2012). Balance training reduces fear of falling and improves dynamic balance and isometric strength in institutionalized older people: a randomised trial. *Journal of Physiotherapy*, 58, 97-104.

[2] Kuzuya, M. (2015). The Cutting-edge of Medicine; Sarcopenia and frailty in super-aged society. *The Journal of the Japanese Society of Internal Medicine*, 104(12), 2602-2607.

[3] Morley, J. E. (2016). Frailty and sarcopenia in elderly. *Springer-Verlag Wien*, s439-s445.

[4] Kasahara, M., Yamasaki, H., Aoki, U., Yokoyama, H., Omori, Y., & Hiraki, K. (2001). Relationship between one leg standing time and knee extension strength in elderly patients. *The Japanese Journal of Physical Fitness and Sports Medicine*, 50, 369-374.

[5] Takakura, S., Ohgi, S., & Akiyama, T. (2004). Standing postural control test using the elderly balance board type N and predicting falls. *Journal of the Japanese Physical Therapy Association*, 31(6), 364-368.

[6] Murata, S., Tsuda, A., Inatani, F., & Tanaka Y. (2005). Physical and cognitive factors associated with falls among the elderly with disability at home. *Journal of the Japanese Physical Therapy Association*, 32(2), 88-95.

[7] Murata, S., Kai, Y., Mizota, K., Yamasaki, S., Yumioka, M., Otao, H., & Takeda, I. (2006). Relationship between one-leg standing duration with vision and physical function among community dwelling older adults. *Rigakuryoho Kagaku*, 21(4), 437-440.

[8] Murata, S. & Tsuda, A. (2006). A prospective study of the relationship between physical and cognitive factors and falls in the elderly disabled at home. *Journal of the Japanese Physical Therapy Association*, 33(3), 97-104.

[9] Hirase, T., Inokuchi, S., Shiozuka, J., Nakahara, K., & Matsusaka, N. (2008). Relationship between balance ability and lower extremity muscular strength in the elderly: Comparison by gender, age, and Tokyo Metropolitan Institute of Gerontology (TMIG) index of competence. *Rigakuryoho Kagaku*, 23(5), 641-646.

[10] Uchida, Y., Demura, S., & Hirai, H. (2018). Influence of hand help pressure on body sway and leg muscle activity during one-leg stance. *Advances in Research*, 17(5), 1-9.

[11] Shibata, Y., Okada, E., Nakamura, M., & Ojima, T. (2021). Effects of locomotion training in community-dwelling older individuals attending clubs. *Nihon Koshu Eisei Zasshi*, 68(3), 180-185.

[12] Uchida, Y. & Demura, S. (2016). Body sway and muscle activity during assisted one-and two-leg stances in the elderly, *Advances in Research*, **7**(3), 1-9.

[13] The Japanese Orthopaedic Association. (2021). The brochure of locomotion in Japan, 2013. https://www.med.or.jp/dl-med/doctor/ssi/sports25/sports25_k14.pdf.

[14] Hayashi, F., Asai, Y., Morimoto, H., Maruyama, T., Watanabe, M., Lohman E. B., Johnson E. G., & Kashiwa, N. (2012). The postural control in different conditions among the healthy elderly person. *Journal of Health Sciences, Nihon Fukushi University*, 15, 11-16.

[15] Suzuki, Y., Nakata, Y., Kato, H., Tanabe, Y., Iwabuchi, S., & Ishikawa, K. (2015). Association between age and dynamic balance capability assessed by use of force plates. *The Japanese Journal of Physical Fitness and Sports Medicine*, 64(4), 419-425.

[16] Morita, M., Urabe, Y., Takeuchi, T., & Maeda, N. (2018). Effects on ankle muscle activity of the tilt direction of a balance board. *Rigakuryoho Kagaku*, 33(3), 395-400.

[17] Kitabayashi, T., Shinichi, D., Yamaji, S., Nakada, M., Noda, M., & Imaoka, K. (2002). Gender differences and relationships between physical parameters on evaluating the center of foot pressure in static standing posture. *Equilibrium Research*, 61(1), 16-27.

[18] Oyama, Y., Murayama, T., & Ohta, T. (2019). Influence of standing posture on a stable surface affecting center-of-pressure sway and stability in standing posture on an unstable surface in middle-aged women. *Japan Journal of Test and Evaluation of Physical Education and Sports*, 18, 59-69.

[19] Cohen, J. (1988). Statistical power analysis in the behavioral sciences, 2nd Edition, Academic Press.

[20] Ministry of Health, Labour and Welfare. (2019). II. Results of physical status survey, The National Health and Nutrition Survey in Japan, 2019, 115-168. https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryou/kenkou/eiyou/r1-houkoku_00002.html.

[21] Jackson, A., Jackson A. S., & Bell, J. (1980). A comparison of alpha and the intraclass reliability coefficients. *Research Quarterly for Exercise and Sport*, 51, 568-571.

[22] Tabachnick, B. G. & Fidell, L. S. (2006). Using multivariate statistics. *5th International Edition, Boston, MA: Pearson/Allyn & Bacon.*

[23] Demura, S., Yamaji, S., Noda, M., Kitabayashi, T., & Nagasawa, Y. (2001). Examination of parameters evaluating the center of foot pressure in static standing posture from the viewpoints of trial-to-trial reliability and interrelationships among parameters. *Equilibrium Research*, 60 (1), 44-55.

[24] Aoki, H., Demura, S., Yamaji, S., Nagasawa, Y., Nakatani, T., & Nadamoto, M. (2023). Sex and age-level differences of center of pressure sway variables and their inter-relations during static standing posture in healthy people. *The Journal of Education and Health Science*, 68 (4), 247-257.

[25] Ogaya, S., Ikezoe, T., Tsuboyama, T., & Ichihashi, N. (2009). Postural control on a wobble board and stable surface of young and elderly people. *Rigakuryoho Kagaku*, 24 (1), 81-85.

[26] Gatev, P., Thomas, S., Kepple, T., & Hallett, M. (1999). Feedforward ankle strategy of balance during quiet stance in adults. *The Journal of Physiology*, 514(3), 915-928.

[27] Loram, I. D., Kelly, S. M., & Lakie, M. (2001). Human balancing of an inverted pendulum: is sway size controlled by ankle impedance? *The Journal of Physiology*, 532(3), 879-891.

[28] Winter, D. A., Patla, A. E., Ishac, M., & Gage, W. H. (2003). Motor mechanisms of balance during quiet standing. *Journal of*

Electromyography and Kinesiology, 13(1), 49-56.

[29] Fujiwara, K., Murata, S., Kamijou, K., Komatsu, Y., Nagasumi, T., Horie, J., Kubo, A., & Aoyama, H. (2012). Generation and sex differences of the body function of elderly person's participating in long-term care prevention projects. *West Kyushu Journal of Rehabilitation Sciences*, 5, 33-36.

[30] Shiota, K., Hosoda, M., Takanashi, A., Matsuda, M., Miyajima, S., Aizawa, J., & Ikeda, M. (2008). The relationship between muscle power and balance in postural control. *Rigakuryoho Kagaku*, 23(6), 817-821.