American Journal of Sports Science and Medicine, 2017, Vol. 5, No. 1, 1-4
Available online at http://pubs.sciepub.com/ajssm/5/1/1

DOI:10.12691/ajssm-5-1-1

Eyes Open/Closed Conditions and Age-level Differences in Foot Pressure during Stepping with a Stipulated Tempo

Hiroki Aoki[1,*], Shinichi Demura[2], Masato Ohno[3]

[1]National Institute of Technology, Fukui College, General course, Fukui, Japan
[2]Kanazawa University, Ishikawa, Japan
[3]National Institute of Technology, Yonago College, General course, Tottori, Japan
*Corresponding author: aoki@fukui-nct.ac.jp

Abstract A certain pressure (static load) acts as grounding to support the human body during static standing. However, a pressure load from the leg (dynamic load) changes with time and may differ between stepping in place with eyes open and closed. This study aimed to examine the difference in foot pressure between the eyes open and closed conditions and among age-levels during stepping with a stipulated tempo. The participants were 86 healthy men aged between 10 and 80 years. Sample sizes for each decade's age group ranged from 10 to 13. We measured their foot pressure while they stepped 20 times while matching a tempo of 100 bpm. A mean of left–right foot pressure (ratio of pressure to weight) of 20 times was used as an evaluation parameter. Stepping with eyes open and closed produced a significant, strong relationship (r = 0.90) in the foot pressure value. In the results of two-way ANOVA (eyes open/closed difference and age-level difference) and multiple comparisons, eye conditions showed a significant difference only in participants who were in their 80s, with greater foot pressure with eyes open. When stepping with eyes open, 10 and 20 age-levels had greater foot pressure than 50 to 80 age-levels, and 30 to 60 had greater pressure than 70 and 80 age-levels. When stepping with eyes closed, 10 and 20 age-levels had greater pressure than 40 to 80 age-levels, and 30 to 80 had greater pressure than 70 and 80 age-levels. Although the foot pressure value showed a significant linear regression with age both with eyes open and closed, an insignificant difference was found between regression coefficients. In conclusion, regardless of eyes open or closed, the foot pressure value during stepping with a stipulated tempo decreases with age and is low in the eyes closed condition compared to eyes open in the super elderly over 80-years-old, thus differing from other age-levels.

Keywords: *aging, step, dynamic balance*

Cite This Article: Hiroki Aoki, Shinichi Demura, and Masato Ohno, "Eyes Open/Closed Conditions and Age-level Differences in Foot Pressure during Stepping with a Stipulated Tempo." *American Journal of Sports Science and Medicine*, vol. 5, no. 1 (2017): 1-4. doi: 10.12691/ajssm-5-1-1.

1. Introduction

Human beings normally maintain stable posture by integrating vestibular, visuosensory, and somatosensory information from the central nervous system [5]. Among these three senses, the visual system plays a very important role in maintaining a stable posture. Many researchers have observed that decreased visual function greatly affects postural control [13]. The elderly depend more on visual information in postural control than youth [12], and their postural sway when walking differs between conditions when they have their eyes open or closed (Brenton et al., 2011). Moreover, their COP differs between conditions with eyes open and closed [11]. In addition, Aoki et al. [1] examined the difference between eyes open and closed conditions in COP during stepping and age-level difference; they reported that regardless of whether the eyes are open or closed, age levels under 60 hardly differ in COP sway during stepping. Compared to those in their 70s, those in their 80s have a greater COP sway with eyes open; and compared to those under 60, those in their 70s have a greater sway with eyes closed.

Till date, relationships between human foot pressure when standing still and balance or movement ability have been examined [11,15]. According to Akiyama's (1999) report, people with a high foot pressure ratio (affected side foot pressure/all foot pressure quantity) have smaller COP sway. In hemiplegic patients, Sugawara et al. [15]reported finding a close relationship between the lower limbs' foot pressure ratio and walking velocity. Hara and Kubo [7] examined whether the lower limb's loading force value during sitting can be used as an independent judgment of transfer ability in elderly patients with impairments; these researchers suggested that the value closely reflects their transfer ability and can be used to judge their independent or non-independent transfer ability accurately. In other words, in handicapped people, the lower limb's foot pressure when standing still relates to COP and movement. However, few studies are available on this relationship between movements that change the

support base such as walking and going up and down stairs.

As noted above, the super elderly, in their 70s or 80s, have greater body sway during stepping, particularly in the eyes closed condition [1]. Because the super elderly have marked decreases in various physical functions, including balance and leg strength, stepping while maintaining stable posture is very difficult. Stepping with eyes closed is more difficult because they must step while depending only on somatosensory and vestibular information. According to Aoki et al. [1], the super elderly fear falling when stepping with eyes closed. Fear of falling makes it difficult to step strongly because the elderly take posturally safe strategies during step movement and that also reflects foot pressure during stepping. In this situation, we assume that the elderly have low foot pressure during stepping and great difference between foot pressure with eyes open and closed. Knowledge obtained in this study will offer useful information for evaluating leg dysfunction in the elderly.

Therefore, this study examined the difference between eyes open and closed and age-level differences in foot pressure during stepping at a stipulated tempo.

2. Methods

2.1. Participants

The participants were 86 healthy men aged between 10 and 90 years. Table 1 shows means of age, height, and weight of each group. We explained the experiment's purpose, methods, and risks and then obtained their consent. This experimental protocol was approved by the Kanazawa University Health & Science Ethics Committee (approval number: 2012-03).

Table 1. Basic statistics of participants' age, height, and weight

	Age(year)		Height(cm)		Weight(kg)	
	Mean	SD	Mean	SD	Mean	SD
10-year-old	16.3	1.7	169.9	5.2	56.9	6.8
20-year-old	22.3	2.0	173.6	4.5	69.0	8.0
30-year-old	34.6	2.2	173.2	4.2	78.6	5.6
40-year-old	45.8	2.0	171.8	2.9	77.9	13.5
50-year-old	54.8	2.6	170.3	4.3	70.8	9.2
60-year-old	64.9	3.3	164.0	4.7	64.7	9.0
70-year-old	74.4	3.0	159.5	7.6	57.9	12.0
80-year-old	83.4	3.4	160.3	7.1	58.6	9.3

2.2. Materials and Methods

A stabilometer (G-620; Anima, Tokyo, Japan) was used to measure foot pressure during stepping. This machine can calculate the vertical load's foot pressure from values of three vertical foot pressure sensors, which are located at an isosceles triangle's corners, on a level surface. The data sampling frequency was 100 Hz. The participants stood on two platforms (two pieces, left and right), with their arms held comfortably to their sides. They were instructed to focus their eyes on the central fixation target (eyes-open condition) and to close their eyes calmly (eyes-closed condition). After that, they were instructed to step (to walk in place) 40 times, matching a beeping sound of 100 bpm. Each trial was conducted once in each condition: eyes open and eyes closed. A mean of left–right foot pressures of 20 steps was selected as an evaluation parameter. Foot pressure was calculated by dividing the foot pressure value during the stepping phase by the participant's weight (ratio of foot pressure to weight) to eliminate any effect of weight.2.3.

2.3. Statistical Analysis

Pearson's correlation and partial correlation coefficients (considering the age effect) were calculated to examine relationships among evaluation parameters. Two-way ANOVA (one-factor repeated measures) was used to clarify the mean difference of age-levels and eyes open and eyes closed for parameters. When a significant interaction or main effect was found, a Tukey's Honestly Significant Difference (HSD) test was used for multiple comparisons. Linear regression was calculated to examine the relationship among eyes open/closed, foot pressure, and age; this coefficient's significant difference was then tested. A Bartlett test was used to clarify the homoscedasticity of variance. The level of significance was set a priori to 0.05.

3. Results

Table 2 shows correlations between foot pressure with eyes open and eyes closed and among age, height and weight, and foot pressure in eyes open and eyes closed and their partial correlations after eliminating an age effect. Correlations and partial correlations were significant and high (0.90–0.90) between eyes open and eyes closed. Correlations between age and foot pressure in eyes open and eyes closed were significant, but under the moderate level (r = 0.90). Height showed significant correlation, but not partial correlation, with foot pressure in the eyes closed condition.

Table 2. Correlation matrix (lower line) and partial correlation matrix (upper line)

	Age	Height	Weight	Foot pressure in eyes open	Foot pressure in eyes closed
Age(48.0±23.3year)					
Height(168.0±7.3cm)	-0.63*		0.60*	-0.09	-0.03
Weight(66.5±11.9kg)	-0.19	0.58*		-0.06	-0.06
Foot pressure in eyes open(75.0±5.0%)	-0.29*	0.12	0.00		0.90*
Foot pressure in eyes closed(73.7±4.9%)	-0.42*	0.24*	0.03	0.90*	

*p<0.05.

Table 3. Results of two-way ANOVA (age, eyes open, eyes closed)

	Eyes Open(%)		Eyes Closed(%)			
	Mean	SD	Mean	SD	F-value	Post-Hoc
10-year-old	76.3	4.6	75.9	3.5	F1: 2.52*(7,78)	80 year-old: Eyes Open>Eyes Closed
20-year-old	77.7	2.6	77.0	3.3	F2: 34.42*(1,78)	Eyes Open(age-levels) 10, 20>50~80; 30~60>70.80; 70>80
30-year-old	75.2	4.2	73.9	4.3	F3: 1.58(7,78)	Eyes Closed(age-levels) 10.20>40~80; 30~60>70.80
40-year-old	76.3	4.5	74.2	4.6		
50-year-old	74.4	3.7	73.3	3.5		
60-year-old	74.5	3.5	73.9	3.7		
70-year-old	71.8	7.3	69.8	6.7		
80-year-old	73.1	7.0	70.4	5.6		

*p<0.05, F1: eyes open and eyes closed, F2: age-levels, F3: interaction.

Table 3 shows results of two-way ANOVA (age, eyes open, eyes closed) for parameters. Foot pressure was significantly greater in eyes open than in eyes closed conditions only in 80-year-olds. In the eyes open condition, it was greater in 10- and 20-year-olds than in 50- to 80-year-olds and in 30- to 60-year-olds than in 70- and 80-year-olds. In the eyes closed condition, it was greater in age-levels of 10- and 20-year-olds than in 40- to 80-year-olds, and in 30- to 60-year-olds than in 70- and 80-year-olds.

Figure 1 shows the plot of means and basic statistics for foot pressures in eyes open and eyes closed conditions in the young (10- & 20-year-olds), adults (30- to 60-year-olds), and the elderly (70- & 80-year-olds) groups. Correlations were significant between foot pressures in eyes open and eyes closed conditions among the three groups (0.89–0.90). A test result of the homoscedasticity of variance showed significant difference in foot pressures in eyes open and eyes closed conditions. Multiple comparisons showed greater variance, with greater individual differences in 70- and 80 year-olds.

Figure 2 shows regression coefficients among foot pressures in eyes open, eyes closed, and age, with a significant value, but not an insignificant difference, in both eye conditions.

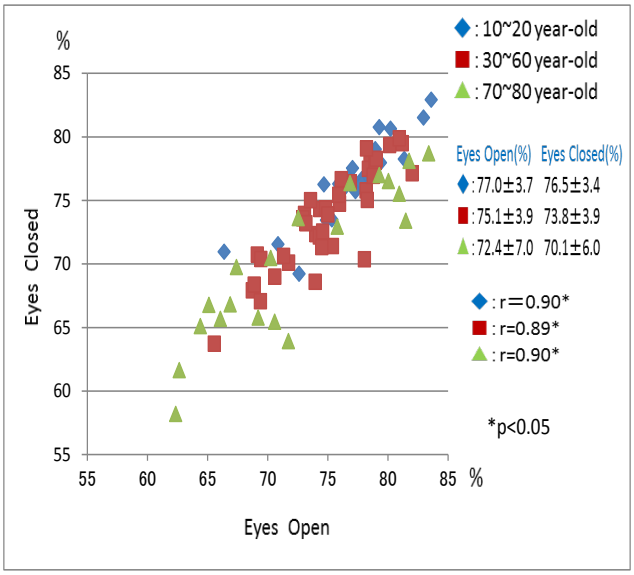

Figure 1. Plot of means and basic statistics for foot pressures in eyes open and eyes closed conditions in young, adult, and elderly people

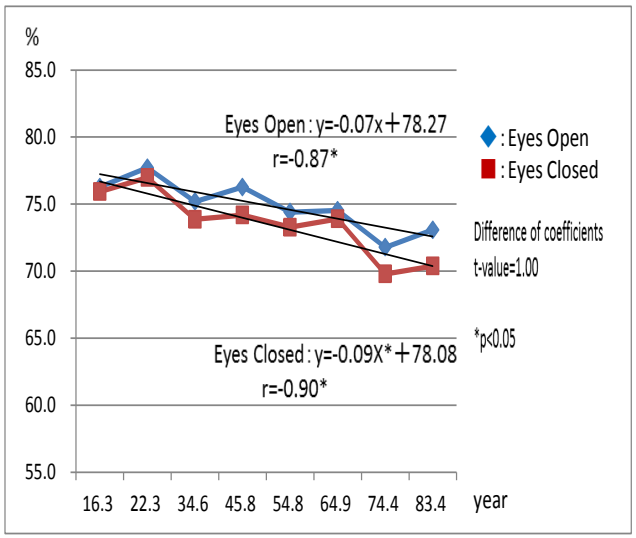

Figure 2. Regression coefficients among foot pressures in eyes open/closed and age

4. Discussion

4.1. Different Tempos

A strong relationship (r = 0.90) was found between foot pressure values during stepping with eyes open/ closed, and a significant, but weak relationship (r = 0.29–0.42) was found with age. The step test with stipulated tempo demands that participants stand on one leg to step in place with their right and left legs while matching the tempo [14]. From the results in this study, we inferred that foot pressure values during stepping with eyes open/closed have a close relationship; however, with increasing age, people face more difficulty in stepping forcefully. Moreover, height showed a weak relationship (r = 0.24) with foot pressure when stepping with eyes closed. Kitabayashi et al. [8] reported that height is related to center-foot pressure. However, the current study's results indicate that its effect on foot pressure during stepping is relatively small. Moreover, weight showed an insignificant relationship with foot pressure. This eliminated the effect of weight (see methods) on other factors.

This study confirmed that the foot pressure value was, as a whole, greater in the young than in the elderly, regardless of whether the eyes were open or closed. Additionally, as

a result of regression analysis, foot pressure decreased in proportion to age (linear regression); the elderly of 70- and 80-years-old, compared to those at other ages, have great individual differences in both eyes open and closed conditions. Lin and Woollacott [10] clarified that leg strength and stability are important factors in maintaining a stable posture and reduced leg strength is associated with balance ability. Young people have greater leg strength than middle-aged and elderly people [11] and are also superior in balance ability [5]. Frontera et al. [6] studied a longitudinal change of muscle strength in the elderly (65.4 ± 4.2 yr), reporting that strength decreases by 1.4–2.5% per year. Moreover, Larson et al. [9] reported that muscle strength decreases by 1.5% per year after 60-years-old. These reports suggest that leg muscles decrease with age, particularly markedly in the elderly over 70 years. In addition, unlike COP is used to evaluate human static balance, stepping with a stipulated tempo, as in this study, demands that the participants step in time to the given tempo; hence, because they are required to stand on one leg, they need to exert great balance ability to maintain stable posture. Presumably, since the 70- and 80-year-old elderly could not step strongly because of reduced balance ability and inferior muscle strength, particularly in the legs, their foot pressure value was low. Furthermore, individual differences in foot pressure values are great because of large individual differences in these abilities.

As stated above, foot pressure was greater with eyes open than with eyes closed only in the 80-year-old elderly. Humans normally maintain a collapsing posture by integrating vestibular, visuosensory, and somatosensory information from the central nervous system [4]. Among these three senses, visuosensory information plays the most important role. If closed eyes intercept visual information, postural control then depends on vestibular and somatosensory information. Buckley et al. [3] reported that an ankle joint's plantar flexion in on-off foot movement during walking was greater in an eyes-closed than in a normal-vision state; those researchers inferred that subjects adopt a cautious strategy by checking the ground with the lead leg. Consequently, the following is inferred: When closed eyes intercept visual information, subjects find it difficult to perform dynamic stepping while maintaining a stable posture. When stepping with eyes closed, the super elderly particular face difficulty, due to fear of falling, and they use posturally safe strategies.

5. Conclusion

Regardless of eyes open or closed, the foot pressure value when stepping with a stipulated tempo decreases with age and is low in the eyes-closed condition in the super elderly over 80-years-old, compared with eyes-open, thus differing from other age-levels.

References

[1] Aoki, H., Demura, S., Kawabata, H., Sugiura, H., Uchida, Y., Xu, N. & Murase, H. (2002). Evaluating the effects of open/closed eyes and age-related differences on center of foot pressure sway during stepping at a set tempo. AAR, 1(3), 72-77.

[2] Asayama, S. (1999). The Influence of the Load-bearing Ability on an Affected Lower Extremity on the Standing Balance of Stroke Hemiplegic Subjects. Rigakuryoho kagaku, 14, 177-180.

[3] Buckley, J.G., MacLellan, M.J., Tucker, M.W., Scally, A.J. & Bennett, S.J. (2008). Visual guidance of landing behavior when stepping down to a new level. Exp Brain Res, 184(2), 223-32.

[4] Demura, S., Kitabayashi, T., Kimura, A. & Matsuzawa, J. (2005). Body sway characteristics during static upright posture in healthy and disordered elderly. J Physiol Anthropol Appl Human Sci, 24(5), 551-555.

[5] Demura, S., Kitabayashi, T., Noda, M. & Aoki H. (2008). Age-stage differences in body sway during a static upright posture based on sway factors and relative accumulation of power frequency. Percept Mot Skills, 107(1), 89-98.

[6] Frontera, W.R., Hughes, V.A., Fielding, R.A., Fiatarone, M.A., Evans, W.J. & Roubenoff, R. (2000). Aging of skeletal muscle: a 12-yr longitudinal study. J Appl Physiol, 88(4), 1321-1326.

[7] Hara, T. & Kubo, A. (2010). Measuring independent transfer ability using lower limb loading force in a sitting position in the impaired elderly. Geriatrics & Gerontology International, 47, 153-157.

[8] Kitabayashi, T., Demura, S., Yamaji, S., Nakada, M., Noda, S. & Imaoka, K. (2002). Gender Differences and Relationships between Physical Parameters on Evaluating the Center of Foot Pressure in Static Standing Posture. Equilibrium Res, 61, 16-27.

[9] Larsson, L., Grimby, G. & Karlsson, J. (1979). Muscle strength and speed of movement in relation to age and muscle morphology. J Appl Physiol, 46(3), 451-456.

[10] Lin, S.I. & Woollacott, M. (2005). Association between sensorimotor function and functional and reactive balance control in the elderly. Age Ageing, 34(4), 358-363.

[11] Matsumura, M., Usa, H., Ogawa, D., Ichikawa, K., Hata, M., Shimizu, Y., Furuya, H., Takei, H. & Shinoda, M. (2015). Age and Gender Differences in Lower Extremity Range of Motion and Muscle Strength: A Cross-sectional Study of Males and Females, Ages 20-70. Rigakuryoho Kagaku, 30, 239-246.

[12] Mizukoshi, K., Watanabe, Y., Nakagawa, H., Asai, M., Ohashi, N. & Shojaku, H. (1993). Age dependent change of postural control. With special reference to visual and proprioceptive influences. Otologia Fukuoka, 39, 745-749.

[13] Paulus, W., Straube, A. & Brandt, T. (1984). Visual stabilization of posture. Physiological stimulus characteristics and clinical aspects. Brain, 107, 1143-1163.

[14] Shin, S. & Demura, S. (2007). Effective tempo of the step test for dynamic balance ability in the elderly. J Physiol Anthropol, 26(6), 563-567.

[15] Sugawara, K., Uchida, S., Ishihara, T., Takahashi, H., Tsubahara, A. & Akaboshi, K. (1993). Relationship between Walking Task Performance and Motor Function in Stroke Patients. Rigakuryoho kagaku, 20, 289-293.