The Relationship between Dynamic Balance Measures and Center of Pressure Displacement Time in Older Adults during an Obstacle Crossing

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Purpose: This study examined the relationship between the center of pressure (COP) displacement time duringthe stance phase and dynamic balance ability when older adults cross a 10 cm obstacle.

Methods: Fifteen older adults were enrolled in this study (all ≥65 years of age). The F-scan was used to measure the COP displacement time when subjects cross a 10 cm obstacle, and the Dynamic gait index. Berg's balance scale and the Four square step test were used to measure dynamic balance ability.

Results: The Dynamic gait index, Berg's balance scale and the Four square step test were correlated with each other. Dynamic balance ability was correlated with COP displacement time during the stance phase at an obstacle crossing in older adults.

Conclusion: People with higher dynamic balance ability show a smaller COP displacement time during the stance phase at an obstacle crossing. Therefore, dynamic balance ability can be predicted by measuring the center of pressure displacement time.

Keywords: Dynamic balance, Center of pressure, Obstacle

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I. Introduction

Dynamic balance is what maintains balance when the body-moves. It is the ability to maintain the desired position and keep the center of gravity within a placed base of support while moving the body.[1] There was a significant positive correlation between aging and dynamic balance, because age-related modifications in dynamic balance make older adults react slower in tasks required for dynamic balance.[2] This reduction in dynamic balance can increase the risk of falls when faced with more challenging environments rather than ground walking at an obstacle crossing.

Obstacle crossing strategies are needed for gait, and the ability to respond to unexpected situations is required. This is especially true if patients with gait disabilities or elderly people face obstacles. They clearly show an abnormal gait pattern and are at increased risk of falls.[3] Loss of walking ability is the first motor impairment that occurs in the elderly due to loss of muscle strength and balance during physical aging. This is the most common cause for falls in the elderly, and it is a direct cause of death in the elderly.[4,5] To prevent falls, many studies have analyzed the characteristics of obstacle crossing.[6-8] Among them, there are studies about characteristics of center of pressure (COP) displacement. The COP during stance phase in normal gait moves along the path and creates a characteristic pattern. So the displacement path of the COP during walking may be an important criterion for judging a normal gait.[9] To measure COP displacement time during the stance phase is a way to measure the time of stance phase accurately. Longer stance time means compensation in abnormal gaits like decreased walking velocity and stride length.[10] Therefore, to measure COP displacement time during the stance phase is an objective method to determine temporal parameters of gait characteristics.

Thus, it is necessary to determine whether the capability for dynamic balance affects the COP displacement time. However, this has not yet been studied. Therefore, our study was designed to analyze the correlation between dynamic balance and COP displacement time at the stance phase during obstacle crossing. To do this, we measured COP displacement time using a foot pressure measurement system when crossing an obstacle 10 cm in height, which is the typical height of steps and curbs.

II. Methods

1. Subjects

Fifteen older adults (5 males, 10 females) were enrolled in this study (all were ≥ 65 years of age). They had no problems in cognitive abilities: their K-MMSE scores were over 24 points, they had no neurological history, and they had the Berg's balance scores of over 41 points, which means a lower risk of falls.[11] Subjects voluntarily agreed to participate in the experiments after listening to the purpose and method of the study.

2. Experimental methods

1) Equipment

The 10 cm obstacle was a circular wooden bar (2 m in length and 2.5 cm in diameter). The obstacle height of 10 cm was chosen based on previous research.[6,12-14] The 10 cm obstacle was designed to be similar to step or curb heights, and is most commonly encountered in daily life. We did measurements three times and calculated, recorded and did analyses with the average.

2) Procedures

The F-scan was used to measure the center of pressure displacement time when crossing an obstacle. The participants wore a converted device on their ankles and waist. Then they put on shoes that had pressure probes (in the insole) tailored to their foot length. Subjects initiated gait or stepped over an obstacle at a self-paced speed.[15] When crossing an obstacle, they were limited to crossing over it with the left foot. We measured the displacement time of the right foot by measuring the step time.

The DGI (Dynamic gait index),[16] BBS (Berg's balance scale)[11] and FSST (Four square step test)[17] were used to measure dynamic balance ability(Figure 1). Subjects had enough break time to avoid fatigue caused by the experiments.

3) Data collection

The F-scan (F-scan version 3.623, Tekscan, USA), the foot pressure measurement system, was used to measure the center of pressure displacement time when crossing an obstacle. Reliability of the F-scan was demonstrated in a previous study.[18-20] It collected 300 frames 22 times a second for 10 seconds at 0.01 seconds per frame. So, one can easily obtain the number of frame and times, including the stance phase.

The stance phase was defined as the moment from heel strike to toe off at the right foot.

3. Data analysis

Spearman analysis was used to characterize the relationship between dynamic balance ability and COP displacement time during obstacle crossing. Simple linear regression tests were used for causal relationships. The independent variables were dynamic balance ability and the dependent variable was COP displacement time during stance phase. Statistical analyses were performed using SPSS ver. 12.0 and p-values less than 0.05 were used to identify significant differences.

III. Results

1. Characteristics of the subjects

The mean age, mean height, mean weight, and mean foot size of the subjects were 72.8±5.2 years, 160.3±5.2 cm, 59.3±5.7 kg, and 249.0±12.1 mm, respectively.

2. Correlations between DGI, BBS and FSST

DGI, BBS and FSST, which measured dynamic balance in this study, were strongly correlated with each other (Table 1).

3. The correlation between dynamic balance ability and COP displacement time

The COP displacement time during stance phase at an obstacle crossing was 1.54±.55 seconds. The means of the three scales – DGI, BBS, FSST – that were measured to investigate dynamic balance ability, were 20.40±3.16, 51.60±3.76, and 21.18±7.64, respectively. Dynamic balance ability was correlated with the COP displacement time during the stance phase at an obstacle crossing in older adults. The COP displacement time was negatively correlated with DGI and BBS, and positively

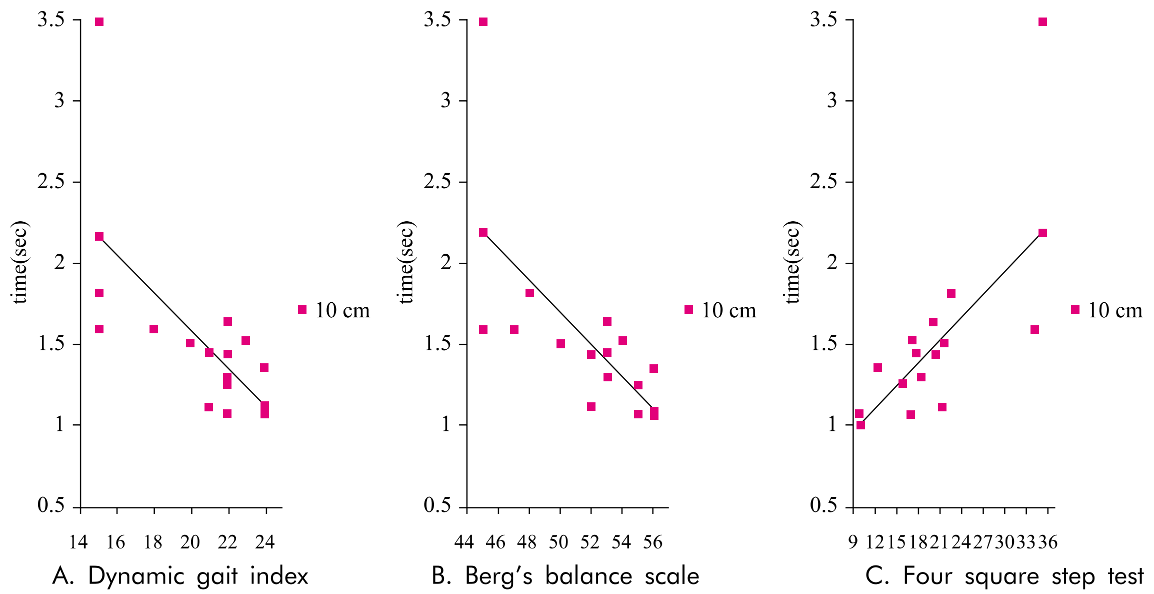

Figure 1. The correlation between dynamic balance abilities and the COP displacement time during stance phase at an obstacle.

correlated with FSST (Table 1). All 3 of these dynamic balance tests were significant to assess COP displacement time during stance phase. DGI, BBS and FSST, respectively, were able to explain 43.3% (Figure 1A), 45.6% (Figure 1B) and 42.5% (Figure 1C) of the variance (Table 2).

IV. Discussion

Obstacle crossing is one of the many complex challenges involving movement during many daily activities and is the most common cause of falls for elderly people.[22,23] One of the biggest causes of poor walking ability is reduced balance,[24] and reduced dynamic balance ability is necessary to maintain balance while moving the body. Unfortunately, balance decreases with age, and is an essential element for obstacle crossing.[1] The 10 cm obstacle was designed to be similar to step and curb heights, and is the most commonly obstacle encountered in daily life. This height was used to analyze the characteristics of obstacle crossings in many previous studies.[6,12-14] Therefore, this study measured COP displacement time and was designed to analyze the correlation of dynamic balance ability and COP displacement time at the stance phase during obstacle crossing.

DGI, BBS and FSST were used to measure dynamic balance

Table 1. The correlation between the DGI, BBS and the FSST, and the correlation between dynamic balance abilities and the COP displacement time during the stance phase at an obstacle

	Dynamic balance		
	DGI	BBS	FSST
Coefficient			
DGI	1	0.92**	-0.91**
BBS		1	-0.99**
FSST			1
COP displacement time	-0.64*	-0.72**	0.73**

*p<0.05
**p<0.01
DGI : Dynamic gait index
BBS : Berg's balance scale
FSST : Four square step test

Table 2. The results of regression between dynamic abilities and the COP displacement time during the stance phase at an obstacle.

	R^2	B (β)	SE	t	p
DGI					
Constant		3.88	0.75	5.16	0.00
Coefficient	0.43	-0.12 (-0.66)	0.04	-3.15	0.01**
BBS					
Constant		6.65	1.56	4.28	0.00
Coefficient	0.46	-0.10 (-0.68)	0.03	-3.30	0.01**
FSST					
Constant		0.72	0.31	2.32	0.04
Coefficient	0.64	0.07 (0.80)	0.01	4.78	0.00**

**p<0.01
DGI: Dynamic gait index
BBS: Berg's balance scale
FSST: Four square step test

ability. The means of the scales were, respectively, 20.40±3.16, 51.60±3.76, and 21.18±7.64. There was a strong correlation between them. This finding is consistent with previous research that found that the FSST has a strong correlation with the DGI. A strongly correlation between DGI and BBS were also found in elderly as well as Parkinson's patients and patients with stroke.[24-26] Subjects who participated in this study had scores of over 41 points on the BBS (41 points means a lower risk of falls).[11,27] So our subjects had little risk of falls. In addition subjects who participated in this study had scores of over 19 points on the DGI (19 points means a higher risk of falls),[27,29] so it indicates that our subjects had little risk of falls. It gives backed the result of this study that the DGI and BBS have a strongly correlation. On the other hand, Dite and Temple[17] found that the most accurate FSST score for identifying multiple fallers is 15 seconds. In this study, subjects who had little risk of falls in the DGI and BBS had scores of over 15 seconds on the FSST. But because we did not measure the number of falls of the subjects, it was difficult to compare with their study directly. So further studies will be needed.

Dynamic balance ability and COP displacement time are correlated during the stance phase at an obstacle crossing in older adults. This means that people with a higher dynamic balance ability show a smaller COP displacement time during the stance phase at anobstacle crossing. The results of this study indicate that when faced with obstacles, older people adopt a slower gait, and dynamic balance ability in older people decrease with age.

The elderly due to loss of dynamic balance ability try to gait more slowly to reduce the risk of falling during obstacle crossing. Therefore, dynamic balance ability can be predicted by measuring the center of pressure displacement time.

V. Conclusion

In this study, the fact that dynamic balance ability affects COP displacement time during stance phase at an obstacle in the elderly was confirmed. The results of this study indicate that when faced with obstacles, older people adopt a slower gait, and dynamic balance ability in older people decrease with age. In order words, people with higher dynamic balance ability show a smaller COP displacement time during the stance phase at an obstacle crossing. We suggest that dynamic balance ability can be predicted by measuring COP displacement time.

Author Contributions

Research design: Park S, Park JW
Acquisition of data: Park S, Park JW
Analysis and interpretation of data: Park S, Park JW
Drafting of the manuscript: Park S, Park JW
Administrative, technical, and material support:
Research supervision: Park JW

References

1. Wade MG, Jones G. The role of vision and spatial orientation in the maintenance of posture. Phys Ther. 1997;77(6):619-28.

2. Kang KH. The effect of aging on static balance and dynamic balance in older adults. The Korean Journal of Physical Education. 200140(4):591-9.
3. Chung HK. The kinematic patterns of walking according to obstacle's height. Journal of The Korean Physical Therapy Science. 2008;15(3):55-63.
4. Overstall PW, Exton-Smith AN, Imms FJ et al. Falls in the elderly related to postural imbalance. Br Med J. 1977;1(6056):261-4.
5. Blake AJ, Morgan K, Bendall MJ et al. Falls by elderly people at home: Prevalence and associated factors. Age Ageing. 1988;17(6):365-72.
6. Han JT, Lee MH, Kim K. The study of plantar foot pressure distribution during obstacle crossing with different height in normal young adults. Korean Journal of Sport Biomechanics. 2008;18(2):1-9.
7. Han JT, Gong WT, Yun SL. Comparison of muscle activity with lower extremity during stairs and ramp climbing of old adults by EMG. J Kor Soc Phys Ther. 2009;21(1):35-40.
8. Park S, Kim K, Park JW. Time difference of the COP displacement according obstacle height during obstacle crossing in older adults. J Kor Soc Phys Ther. 2011;23(2):1-5.
9. Park JW, Nam KS, Back MY. The relationship between the plantar center of pressure displacement and dynamic balance measures in hemiplegic gait. PTK. 2005;12(1):11-21.
10. Kim JW, Eom GM. Comparison of the total stance tine and the phase ratio in parkinson's disease patients and normal subjects. J biomed Eng Res. 2006;27(6):351-6.
11. Berg KO, Maki BE, Williams JI et al. Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil. 1992;73(11):1073-80.
12. Kim HD. The effect of obstacle height on balance control while stepping over an obstacle from a position of quiet stance in older adults. J Kor Soc Phys Ther. 2009;21(3):75-80.
13. Ramachandran AK, Rosengren KS, Yang Y et al. Effect of tai chi on gait and obstacle crossing behaviors in middle-aged adults. Gait Posture. 2007;26(2):248-55.
14. Rosengren KS, McAuley E, Mihalko SL. Gait adjustments in older adults: Activity and efficacy influences. Psychol Aging. 1998;13(3):375-86.
15. Hennig EM, Rosenbaum D. Pressure distribution patterns under the feet of children in comparison with adults. Foot Ankle. 1991;11(5):306-11.
16. Shumway-cook A. Motor control therapy and applications. Williams and Wilkins Baltimore. 1995:323-4.
17. Dite W, Temple VA. A clinical test of stepping and change of direction to identify multiple falling older adults. Arch Phys Med Rehabil. 2002;83(11):1566-71.
18. Brown M, Rudicel S, Esquenazi A. Measurement of dynamic pressures at the shoe-foot interface during normal walking with various foot orthoses using the f-scan system. Foot Ankle Int. 1996;17(3):152-6.
19. Kernozek TW, LaMott EE, Dancisak MJ. Reliability of an in-shoe pressure measurement system during treadmill walking. Foot Ankle Int. 1996;17(4):204-9.
20. Baumhauer JF, Wervey R, McWilliam J et al. A comparison study of plantar foot pressure in a standardized shoe, total contact case, and prefabricated pneumatic walking brace. Foot Ankle Int. 1997;18(1):26-33.
21. Said CM, Goldie PA, Patla AE et al. Effect of stroke on step characteristics of obstacle crossing. Arch Phys Med Rehabil. 2001;82(12):1712-9.
22. Tinetti ME, Speechley M. Prevention of falls among the elderly. N Engl J Med. 1989;320(16):1055-9.
23. Gallagher B, Corbett E, Freeman L et al. A fall prevention program for the home environment. Home Care Provid. 2001;6(5):157-63.
24. Whitney SL, Marchetti GF, Morris LO et al. The reliability and validity of the four square step test for people with balance deficits secondary to a vestibular disorder. Arch Phys Med Rehabil. 2007;88(1):99-104.
25. Lee SH, Hwang BY. The correlations among the dynamic gait index the berg balance scaleand timed up & go test in people with stroke. Journal of The Korean Physical Therapy Science. 2008;15(3):1-8.
26. Hwang SJ, Woo YK. Intrarater and interrater reliability of the dynamic gait index in persons with parkinson's disease. PTK. 2010;17(4):55-60.
27. Shumway-Cook A, Baldwin M, Polissar NL et al. Predicting the probability for falls in community-dwelling older adults. Phys Ther. 1997;77(8):812-9.
28. Park SY, Hwang SJ. Validation of the Korean translated dynamic gait index in community-dwelling elderly. PTK. 2010;17(1):43-52.