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Original Article

Static balance according to hip joint angle of unsupported leg during one-leg standing

Ju-Hyung Cha, PT, BSc[1)], Jang-Joon Kim, PT, BSc[1)], Jae-Gwan Ye, PT, BSc[1)], Seul-Ji Lee, PT, BSc[1)], Jeong-Mi Hong, BSc[1)], Hyun-Kyu Choi, PT, MSc[2)], Ho-Suk Choi, PT, PhD[1)], Won-Seob Shin, PT, PhD[1)*]

[1)] *Department of Physical Therapy, College of Health and Medical Science, Daejeon University: 62 Daehak-ro, Dong-gu, Daejeon 300-716, Republic of Korea*
[2)] *Department of Physical Therapy, Graduate School of Daejeon University, Republic of Korea*

Abstract. [Purpose] This study aimed to determine static balance according to hip joint angle of the unsupported leg during one-leg standing. [Subjects and Methods] Subjects included 45 healthy adult males and females in their 20s. During one-leg standing on the non-dominant leg, the position of the unsupported leg was classified according to hip joint angles of point angle was class. Static balance was then measured using a force plate with eyes open and closed. The total length, sway velocity, maximum deviation, and velocity on the mediolateral and anteroposterior axes of center of pressure were measured. [Results] In balance assessment with eyes open, there were significant differences between groups according to hip joint angle, except for maximum deviation on the anteroposterior axis. In balance assessment with eyes closed, there were significant differences between total length measurements at 0° and 30°, 60° and between 30° and 90°. There were significant differences between sway velocity measurements at 0° and 30° and between 30° and 90°. [Conclusion] Thus, there were differences in static balance according to hip joint angle. It is necessary to clearly identify the hip joint angle during one-leg standing testing.

Key words: Hip joint angle, One-leg standing, Static balance

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INTRODUCTION

Voluntary movements are performed naturally without conscious effort, just as avoidance reactions occur in instantaneous response to sudden external stimuli. These automatic responses require balancing of complex physical structures[1)].

Balance is defined as maintenance of a stable position by adjusting the center of gravity above the basal plane[2)], and as maintenance of the center of gravity during sway[2, 3)]. Segments of the human body are interconnected. Therefore, changed alignment in one segment causes compensatory movement, and can lead to instability[4)]. Body sway is minimized to maintain balance[5)]. Balance ability is the capacity to minimize and stabilize movement of the center of gravity on a basal surface in order to maintain equilibrium under various conditions[6)]. This is essential for optimal performance in activities of daily living[7)]. Balance abilities require integration of sensory information, neurological processes, and biomechanical factors. Moreover, the musculoskeletal system includes visual, vestibular sensory, and proprioceptive sensory integration components[8)].

Static balance ability is assessed with the one-leg standing test, Romberg test, and stork stand test[9)]. Typically, the sense of balance has been assessed using the one-leg standing test, with support on both feet in static balance used as a standard. One-leg standing is an essential component of many movements in daily life, including walking, running, changing direction, using the stairs, and playing sports[10)]. Static balance ability evaluation has been used as a research tool[11)]. One-leg standing is inherently unstable; as visual information is a major contributor to the ability to balance[12, 13)], lack of visual information

*Corresponding author. Won-Seob Shin (E-mail: shinws@dju.kr)

can further amplify instability[14].

One-leg standing based on the center of pressure has been used for balance ability assessment[15]. Center of pressure and balance ability related to studies anteroposterior and mediolateral sway distance range of the center of pressure of time domain variable 95% confidence ellipse area, 95% confidence circle area analysis of the evaluation has been its ability to[16]. Coordinate values for the center of pressure are determined using a force plate and the degree of balance ability is evaluated by using the range, standard deviation, sway area, sway distance, velocity change, and acceleration change. Force plate balance data are used to determine hip joint angle changes[17]. Measured center of pressure data are analyzed using the total length, sway velocity, anteroposterior maximum sway distance and velocity, and mediolateral maximum sway distance and velocity.

Table 1. Characteristics of the subjects (N=45)

Variables	Means ± SD
Age (yrs)	22.8 ± 2.0
Height (cm)	164.8 ± 9.1
Weight (kg)	59.3 ± 10.4
Foot length (mm)	244.6 ± 16.3

In prior research on hip joint ability to maintain balance and compensate for factors affecting the hip joint angle, the subjects themselves chose the angle or the study was conducted using pre-set positions. Thus, there are no clear criteria for hip joint angle in one-leg standing. This study aimed to establish clear criteria for hip joint angle in the one-leg standing test, according to the presence or absence of visual input and changes in the angle. The hypothesis were set up to investigate as follows, there will be a difference on hip joint angle of unsupported leg during one-leg standing; there will be a difference of the degree of balance ability.

SUBJECTS AND METHODS

This study included 45 subjects. The selection criteria were as follows: full range of joint motion; no history of lumbar, pelvic, femoral, or ankle surgery; no hip or ankle pain, and ability to perform a one-leg standing test. The subjects were fully informed about the purpose and methods of the study, and voluntarily agreed to participate in the experiment. The study was approved by the Daejeon University institutional review board. General characteristics including gender, age, height, weight, and foot size were examined before the experiment (Table 1). The angles were selected at random (0°, 30°, 60°, and 90°).

The subjects were assigned to testing according to hip joint angle, with or without visual blocking, for measurement in random order. All angles were tested in the unsupported legs[18].

The Gaitview System (AFA-50, ALFOOTS, Korea) was used to measure balance ability in one-leg standing posture. The Gaitview System has a size of 550 × 480 × 35 mm, a sensor size of 0.75 cm^2 and a sensor number of 2,304 (48 × 48). Data were processed using Gaitview software version 1.0.1 vestibular test mode. Subjects were tested with eyes open or closed.

Experiments were performed without shoes on a force plate. The subjects were prepared while standing on the force plate, with eyes elevated 15°, both hands in anatomic position, and dominant leg lifted. The subjects were excluded if they failed the test more than 5 times with eyes closed. In this study, one-leg standing caused the dominant leg to be lifted and the other leg to provide support. The dominant leg was selected by self-report as the leg used to kick a ball[19]. When static balance ability was measured in one-leg standing, the angle of the hips was set at 0°, 30°, 60°, or 90°, with the eyes closed or open. Verbal instruction was given to maintain balance for 20 seconds. Then, the degree of balance ability was measured. The knee angle was fixed at 90° balance ability the hips was given to maintain posture during measurement.

Joint angle was measured with a goniometer. With the greater trochanter used as the axis, and weight supported with the non-dominant leg, hip angles of 0°, 30°, 60°, 90° angle dominant leg. The experimenter asked the subjects to maintain their balance as much as possible, with the eyes open or closed, and all angles were measured 3 times. A 30-sec break was given between measurements. Thus, with the eyes closed, the measurement time could not be exceeded, and success was achieved after repeated attempts.

The results of this study were analyzed using SPSS ver.18.0. The general characteristics of the study subjects are presented as mean and standard deviation using descriptive statistics; the Shapiro-Wilk test was used to obtain a normal distribution. Two-way repeated analysis of variance (ANOVA) was used to determine the interaction between the presence or absence of visual blocking and the hip flexion angle. Repeated measures ANOVA was used to compare the results of balance data for each hip joint angle, and the Bonferroni method was used for a post-test. The significance level α was set at 0.05.

RESULTS

Of the 45 subjects, 16 were male and 29 were female. The mean age was 22.8 years, mean height was 164.8 cm, mean weight was 59.3 kg, and foot size was 244.6 mm. The characteristics are shown in Table 1.

No significant interaction between hip joint angle and presence or absence of visual blocking was found.

Balance assessment according to hip joint angle with the eyes open were significant differences in total length of sway, sway velocity, mediolateral maximum distance, and velocity, anteroposterior sway velocity ($p<0.05$). In post hoc, there were significant differences between groups at 0° and 30°, 60°, 90° ($p<0.05$). There were no significant differences in all items among groups at 30°, 60°, 90° of hip joint angle ($p>0.05$) (Table 2).

Table 2. Comparison of the balance according to the state of visual and the angle of the hip joint (N=45)

Variables	Visual state	Hip joint angle			
		0°	30°	60°	90°
TL	Open*	372.6 ± 90.2[a]	295.2 ± 91.5†	298.2 ± 62.6†	320.5 ± 78.3†
(mm)	Close*	616.1 ± 131.2	523.1 ± 108.8†‡	557.2 ± 119.7†	599.2 ± 135.7
SV	Open*	18.6 ± 4.5	14.7 ± 4.6†	14.9 ± 3.2†	16.1 ± 3.8†
(mm/s)	Close*	30.8 ± 6.6	26.1 ± 5.5†‡	28.1 ± 5.7	30.0 ± 6.8
ML-vel	Open*	12.1 ± 3.0	9.5 ± 2.7†	10.1 ± 2.5†	10.4 ± 2.4†
(mm/s)	Close*	20.1 ± 4.5	17.5 ± 3.6†‡	18.4 ± 3.9†‡	19.9 ± 4.0
ML-max	Open*	17.3 ± 4.1	14.5 ± 3.4†	15.3 ± 4.1†	14.9 ± 4.0†
(mm)	Close*	25.1 ± 4.2	22.8 ± 4.3‡	23.9 ± 4.6	24.8 ± 3.7†
AP-vel	Open*	12.5 ± 3.6	9.9 ± 3.9†	9.7 ± 2.5†	10.9 ± 3.3†
(mm/s)	Close*	19.4 ± 5.1	16.7 ± 4.3†	17.7 ± 4.3	18.9 ± 5.6
AP-max	Open	20.3 ± 6.0	16.2 ± 4.4	16.4 ± 4.8	18.0 ± 5.8
(mm)	Close	31.6 ± 9.3	27.8 ± 9.1	30.0 ± 8.4	31.9 ± 10.0

[a]Means ± SD, *Significant different among the hip joint angles ($p<0.05$).
†Significant different from 0° ($p<0.05$), ‡Significant different from 90° ($p<0.05$).
TL: total length of sway; SV: sway velocity; ML-vel: mediolateral velocity; ML-max: center of gravity mediolateral maximum deviation; AP-vel: anteroposterior velocity; AP-max: center of gravity anteroposterior maximum deviation

Balance assessment according to hip joint angle with the eyes closed were significant differences in the total length of sway, sway velocity, mediolateral maximum sway distance and velocity, and anteroposterior sway velocity ($p<0.05$). In post hoc, the total length of sway was significantly different between groups at 0° and 30°, 60° and between 30° and 90°. There were significant differences in sway velocity between 0° and 30°, 30° and 90° ($p<0.05$). There were significant differences in mediolateral sway velocity between 0° and 30°, 60°, between 30° and 90°, between 60° and 90° ($p<0.05$). There were significant differences in mediolateral maximum sway distance between 30° and 90° ($p<0.05$). For anteroposterior sway velocity, there was no significant difference between angles except at 0° and 30° ($p>0.05$). There were no significant differences in anteroposterior maximum sway distance for all angles.

DISCUSSION

Hip joints are important for both weight bearing and static and dynamic balance[20]. Recent evidence suggests that hip movements are physically and mechanically significant during static standing posture[21]. In addition, the importance of hip joints for balance ability was reported to be as large as that for ankle joints. However, previous studies did not provide a clear value for the hip joint angle during one-leg standing[22].

The results of this study show that static balance with eyes open has a larger value at 0° than 30°, 60° and 90°. This result show the hip joint angle affects static balance. Modern living conditions with prolonged sitting, lack of exercise, inadequate posture, excessive muscle tension, and abdominal obesity contribute to deformation of the lumbar spine. Changes in body alignment lead to muscle extension and shortening, imbalance in strength of antagonist muscles, or defects in the skeletal system that promote such muscle changes[23]. Repeated overload due to poor posture causes instability. As a result, the stress on the joint differs from that in normal individuals, and fatigue increases. The hip joint anterior ligament shortens and the range of motion of the hip joint becomes limited. The reduction in lumbosacral flexibility and shortening of the quadriceps muscle limit pelvic motion due to the nature of the muscles, fascia, and ligaments of the vertebrae[24]. Shortened hip flexor muscles, and spinal muscles, fascia, and ligaments result in pelvic anterior displacement and excessive lumbar lordosis[25], leading to trunk instability. Thus, it may be that decreased hip joint flexion affects balance ability at a hip joint angle of 0° during one-leg standing.

In this study, we predicted that in static balance with eyes open, the hip joint angle at 90° would also be greater than 30° and 60°. When the hip joint is flexed at 90°, greater muscle force if the length of the external moment arm is greater than the length of the internal moment arm[26]. In addition, during lifting of the hip joint by 90° during the external moment arm is greater than the length of the internal moment arm[27]. This result suggests that there was no significant difference in the 30°, 60° hip joints during one-leg standing, because the body center moved backward into the basal plane.

There was a significant difference at some angles in static balance with eyes closed, but there was no consistency between measurement items. The mean of all measurements was largest at 0° and the smallest at 30°. Balance in the human body consists of a series of controls that determine information received in the central nervous system from the vestibular, somatosensory, and visual organs; the central nervous system then send signals to the muscles to keep the body from falling. The somatosensory and visual organs play an important role in enhancing balance and maintaining balance[28]. These sensory organs have a direct effect on ability to balance, so it is difficult to determine to what extent an institution is involved in balance[29]. Visual information is the most influential factor in posture control[13]. This study showed that visual acuity had more influence on balance ability than hip joint angle change.

In this study, anteroposterior maximum sway distance was larger than mediolateral maximum sway distance. When the hip joint angle is flexed to 30°, 60°, and 90° during one-leg standing, based on the third lever principle, a larger muscle force is used[30], and the center of gravity moves forward from the base[29]. At the hip joint angle 0°, a shortened hip joint flexor causes couple force to occur, resulting in pelvic anterior tilt displacement, excessive lumbar lordosis to trunk instability[26]. For this reason, anteroposterior maximum sway distance seems to be greater than mediolateral maximum sway distance.

This study has some limitations. First, the number of subjects was small, and they were in their 20s. Therefore, it is difficult to generalize to all ages. Second, one-leg standing was not accurately controlled according to the hip joint angle. Third, it was difficult to precisely control the alignment of the body except for the hip and knee angle when measuring static balance. Future research will be needed to overcome these limitations.

This study was conducted on 45 healthy male and female subjects in their 20s. One-leg standing was performed to assess static balance ability according to hip joint angle. The highest 0° hip joint was observed in all measured values except anteroposterior maximum sway distance with eyes open. However, with eyes closed, the mean of all measurements was the largest at 0° hip joint angle and the smallest at 30°. Therefore, it is necessary to clarity the angle of the hip joint when evaluating one-leg standing static balance.

REFERENCES

1) Horak FB, Henry SM, Shumway-Cook A: Postural perturbations: new insights for treatment of balance disorders. Phys Ther, 1997, 77: 517–533. [Medline] [CrossRef]
2) Nichols DS, Glenn TM, Hutchinson KJ: Changes in the mean center of balance during balance testing in young adults. Phys Ther, 1995, 75: 699–706. [Medline] [CrossRef]
3) Karlsson A, Frykberg G: Correlations between force plate measures for assessment of balance. Clin Biomech (Bristol, Avon), 2000, 15: 365–369. [Medline] [CrossRef]
4) Siqueira CM, Lahoz Moya GB, Caffaro RR, et al.: Misalignment of the knees: does it affect human stance stability. J Bodyw Mov Ther, 2011, 15: 235–241. [Medline] [CrossRef]
5) Gur G, Dilek B, Ayhan C, et al.: Effect of a spinal brace on postural control in different sensory conditions in adolescent idiopathic scoliosis: a preliminary analysis. Gait Posture, 2015, 41: 93–99. [Medline] [CrossRef]
6) Tsai LC, Yu B, Mercer VS, et al.: Comparison of different structural foot types for measures of standing postural control. J Orthop Sports Phys Ther, 2006, 36: 942–953. [Medline] [CrossRef]
7) Boyas S, Remaud A, Bisson EJ, et al.: Impairment in postural control is greater when ankle plantarflexors and dorsiflexors are fatigued simultaneously than when fatigued separately. Gait Posture, 2011, 34: 254–259. [Medline] [CrossRef]
8) Hwang S, Agada P, Grill S, et al.: A central processing sensory deficit with Parkinson's disease. Exp Brain Res, 2016, 234: 2369–2379. [Medline] [CrossRef]
9) Rad LS, Mamashi Z, Sadeghi H: A comparison of common methods for static, semi-dynamic, and dynamic balance assessmentin 12 to 15 year old girls with different somatotypes. Intl j Sport Std, 2013, 3:1137–1148.
10) Jonsson E, Seiger A, Hirschfeld H: One-leg stance in healthy young and elderly adults: a measure of postural steadiness? Clin Biomech (Bristol, Avon), 2004, 19: 688–694. [Medline] [CrossRef]
11) Frzovic D, Morris ME, Vowels L: Clinical tests of standing balance: performance of persons with multiple sclerosis. Arch Phys Med Rehabil, 2000, 81: 215–221. [Medline] [CrossRef]
12) Simoneau GG, Ulbrecht JS, Derr JA, et al.: Postural instability in patients with diabetic sensory neuropathy. Diabetes Care, 1994, 17: 1411–1421. [Medline] [CrossRef]
13) Teasdale N, Simoneau M: Attentional demands for postural control: the effects of aging and sensory reintegration. Gait Posture, 2001, 14: 203–210. [Medline] [CrossRef]
14) Caudron S, Guerraz M, Eusebio A, et al.: Evaluation of a visual biofeedback on the postural control in Parkinson's disease. Neurophysiol Clin, 2014, 44: 77–86. [Medline] [CrossRef]
15) Bohannon RW, Leary KM: Standing balance and function over the course of acute rehabilitation. Arch Phys Med Rehabil, 1995, 76: 994–996. [Medline] [CrossRef]
16) Doyle RJ, Hsiao-Wecksler ET, Ragan BG, et al.: Generalizability of center of pressure measures of quiet standing. Gait Posture, 2007, 25: 166–171. [Medline] [CrossRef]
17) Horak FB: Clinical measurement of postural control in adults. Phys Ther, 1987, 67: 1881–1885. [Medline] [CrossRef]
18) Ochsendorf DT, Mattacola CG, Arnold BL: Effect of orthotics on postural sway after fatigue of the plantar flexors and dorsiflexors. J Athl Train, 2000, 35: 26–30. [Medline]
19) Bizid R, Margnes E, François Y, et al.: Effects of knee and ankle muscle fatigue on postural control in the unipedal stance. Eur J Appl Physiol, 2009, 106: 375–380. [Medline] [CrossRef]
20) Ferreira GE, Viero CC, Silveira MN, et al.: Immediate effects of hip mobilization on pain and baropodometric variables—a case report. Man Ther, 2013, 18: 628–631. [Medline] [CrossRef]

21) Suzuki Y, Nomura T, Casadio M, et al.: Intermittent control with ankle, hip, and mixed strategies during quiet standing: a theoretical proposal based on a double inverted pendulum model. J Theor Biol, 2012, 310: 55–79. [Medline] [CrossRef]
22) Yoshimoto Y, Oyama Y, Tanaka M, et al.: One-leg standing time of the affected side moderately predicts for postdischarge falls in community stroke patients. J Stroke Cerebrovasc Dis, 2016, 25: 1907–1913. [Medline] [CrossRef]
23) Hrysomallis C, Goodman C: A review of resistance exercise and posture realignment. J Strength Cond Res, 2001, 15: 385–390. [Medline]
24) Han HI, Choi HS, Shin WS: Effects of hamstring stretch with pelvic control on pain and work ability in standing workers. J Back Musculoskeletal Rehabil, 2016, 29: 865–871. [Medline] [CrossRef]
25) Anderson K, Strickland SM, Warren R: Hip and groin injuries in athletes. Am J Sports Med, 2001, 29: 521–533. [Medline]
26) Neumann DA: Biomechanical analysis of selected principles of hip joint protection. Arthritis Care Res, 1989, 2: 146–155. [Medline] [CrossRef]
27) Lewis CL, Sahrmann SA: Effect of posture on hip angles and moments during gait. Man Ther, 2015, 20: 176–182. [Medline] [CrossRef]
28) Vuillerme N, Nougier V, Prieur JM: Can vision compensate for a lower limbs muscular fatigue for controlling posture in humans? Neurosci Lett, 2001, 308: 103–106. [Medline] [CrossRef]
29) Winter DA: Human balance and posture control during standing and walking. Gait Posture, 1995, 3: 193–214. [CrossRef]
30) Jung HS, Jeon HS, Oh DW, et al.: Effect of the pelvic compression belt on the hip extensor activation patterns of sacroiliac joint pain patients during one-leg standing: a pilot study. Man Ther, 2013, 18: 143–148. [Medline] [CrossRef]