J. Phys. Ther. Sci.
25: 997–1000, 2013

Analysis of Balance Ability Dependent on the Angle of the Knee Joint in Females in Their 20s

Se-Won Yoon, PhD[1)], Jeong-Woo Lee, PhD[1)*], Woon-Su Cho, PhD[2)], An-Na Kim[3)], Kyung-Hee Lee, PhD[4)]

[1)] *Department of Physical Therapy, Kwangju Women's University: 165 Sanjeong-dong, Gwangsan-gu, Gwangju 506-713, Republic of Korea. TEL: +82 2-62-950-3659, FAX: +82 2-62-950-3882*
[2)] *Department of Physical Therapy, Nambu University*
[3)] *Sports Science Research Institute of Chosun University*
[4)] *Department of Physical Therapy, Dongnam Heath College*

Abstract. [Purpose] The aim of this study was to investigate how balance ability according to angle of the knee joint changes in young female adults wearing a knee orthosis. [Methods] This study was conducted with 11 healthy female adults. The subjects used a knee brace that could be set to angles of 0°, 15°, and 30° of knee flexion. The ability to balance was evaluated by balance assessment. A total of four postures were used for measurements: a forward-facing posture with the eyes open on a stable surface (NO), a forward-facing posture with the eyes closed on a stable surface (NC), a forward-facing posture with the eyes open on an unstable surface (PO), and a forward-facing posture with the eyes closed on an unstable surface (PC). [Results] Regarding the weight distribution index and stability index on a stable surface, there was no interaction according to whether there was visual deprivation or not or according to knee flexion angle. Furthermore, the stability index on an unstable surface showed no interaction according to whether there was visual deprivation or not or according to knee flexion angle. But the WDI on a stable surface showed no interaction according to whether there was visual deprivation or not or according to knee flexion angle. [Conclusion] There were significant differences in the knee extension range of motion of normal elderly people and knee osteoarthritis, and the quadriceps femoris played an important role in knee function in individuals with knee osteoarthritis.

Key words: Osteoarthritis, Knee orthosis, Balance

(This article was submitted Feb. 8, 2013, and was accepted Apr. 8, 2013)

INTRODUCTION

As a capacity to control and maintain the center of gravity (COG) above the base of support, balance is a process to continuously maintain posture stability[1)]. It has important influences on maintenance of stability in a standing posture, control of body weight load, and practice of movements of walking ability[2)]. Balance enables us to walk well, not fall down, and properly perform all our work in daily life[3)].

Factors affecting balance are knee joint flexion, difference in leg length, location of foot, age, input of visual sense, gender, loss of proprioceptive sense (joint, muscle, sinew, and mechanical receptors in related structures), breath, nervous disease, height, muscular tension that allows one to efficiently adapt to changing environments, muscular strength and endurance, flexibility of joint, etc[4)]. If even one part of these factors is defective, body balance ability will be reduced, and this would limit movement in daily life. Furthermore, as a secondarily consideration, risk of injury from falls would increase[5)].

According to several studies, postural sway increases and control of posture balance deteriorates due to damage to or diseased state of joints[6–9)]. Wegener et al.[9)] said that knee osteoarthritis makes the knee joint unstable and reduces the range of motion of the knee joint, which leads to difficulty in controlling balance in daily life. Such knee osteoarthritis can be a cause of injury from falls due to decreased balance ability[10, 11)].

Both limitation of range of motion (ROM) of a lower limb joint and weakened muscular strength of a lower limb are important causes of injury from falls[12)]. Whipple et al.[13)] compared the lower limb muscle group of the hip joint, knee joint, and ankle joint in persons who had experienced an injury from a fall with those of persons who had not experienced an injury from a fall to understand the relationship between injuries from falls and lower limb muscular strength. The results showed theat the lower limb muscles of the persons who experienced an injury from a fall became weakened compared with persons who did not experience an injury. Ostrosky et al.[14)] compared the characteristics of walking in healthy young adults and the aged. The results showed that the aged exhibited smaller knee extension than young adults and that the aged had a shorter stride length than young adults. This means that with regard to lower limb muscular strength, weakening of knee muscular strength is an important factor as a cause of injury from falls, which reduces balance ability[4)].

*To whom correspondence should be addressed.
E-mail: jwlee@kwu.ac.kr

In physiotherapy, there have been many studies about lower limb balance ability for the ankle joint. But there are few studies of the knee joint with regard to balance ability. Therefore, the purpose of this study was to investigate balance ability according to change in the angle of the knee joint; in this study, young female adults wore a knee orthosis. Furthermore, this study aimed to provide basic information about trends in changes in balance ability in patients with knee osteoarthritis.

SUBJECTS AND METHODS

The subjects of this study were 11 healthy female adults in their 20s who were studying at K University. Before the experiment, a suffieicent explanation was given to subjects, and written consent for participation in the experiment was obtained from them. The subjects were selected so that the following persons were excluded: persons with disorder of the musculoskeletal system or nervous system, persons with experiences of excessive exercise in the past six months, persons taking medicine related to lower limb muscular strength, and persons who have trouble in their daily life. The average age of the subjects was 20.9±0.8, average height was 159.5±3.9 cm, and average weight was 54.3±5.6 kg (Table 1).

Table 1. General characteristics of the subjects (n= 11)

	Subjects
Age (yrs)	020.9±0.8
Weight (kg)	054.3±5.6
Height (cm)	159.5±3.9

Mean±SD

A balance test was performed at each angle of knee flexion using a Tetrax balance measuring instrument (Tetrax, Sunlight Medical, Ramat Gan, Tel Aviv, Israel). The subjects rested for 1 to 2 minutes between each knee flexion angle when assessing balance ability. A knee orthosis (Donjoy orthosis, Sol Orthosis Corporation, Korea) Was used to ensure the correct knee flexion angles. It was worn with the knee bent at about 90°, and the middle point of the orthosis was placed at the side of the knee. The bending angle was then adjusted to 0°, 15°, and 30° for analysis of balance ability.

A total of four postures were used for measurements: a forward-facing posture with the eyes open on a stable surface (NO), a forward-facing posture with the eyes closed on a stable surface (NC), a forward-facing posture with the eyes open on an unstable surface (PO), and a forward-facing posture with the eyes closed on an unstable surface (PC). During assessment, each posture was maintained for 32 seconds, and the subjects were asked to remain were silent and to not move that the posture of the upper half of the body. When measuring each posture, assessment was performed after confirming that the posture was stable for 10 seconds.

The weight distribution index (WDI) and stability index (ST) were analyzed using the Tetrax software; before the analysis, data concerning the pressure applied to the footholds on which the study subjects stood were amplified and filtered. WDI refers to the degree of weight distributed to the four footholds; a normal value is between 4 and 6 (ratio of weight is 25%).

A higher WDI indicates a diseased state. A low WDI indicates excessive stiffness of posture[15]. ST refers ot overall stability measured by degree of the swaying of posture on the four footholds. This index is used to assess the ability to adjust and compensate for change in posture. A higher ST indicates more instability[15, 16].

All the data in this study were analyzed using the SPSS 12.0 software. For analysis of changes in balance ability according to knee flexion angle and whether there was visual deprivation or not, two-way ANOVA with repeated measures was performed. The α level for statistical significance was set at 0.05.

RESULTS

The result of two-way ANOVA with repeated measures for WDI on a stable surface showed that there was no interaction according to whether there was visual deprivation or not or according to knee flexion angle. There was no statistically significant difference in the change in WDI according to whether there was visual deprivation or not. There was also no statistically significant difference in the change in WDI according to knee flexion angle (Table 2).

The results of two-way ANOVA with repeated measures for WDI on an unstable surface showed that there was interaction according to whether there was visual deprivation or not or according to knee flexion angle. There was a statistically significant difference in the change in WDI ($p<0.05$). But there was no statistically significant difference in the change in WDI according to whether there was visual deprivation or not or according to knee flexion angle (Table 3).

The results of two-way ANOVA with repeated measures for ST on a stable surface showed that there was no interaction according to whether there was visual deprivation or not or according to knee flexion angle ($p>0.05$). There was a statistically significant difference in the change in ST according to whether there was visual deprivation or not ($p<0.05$). But there was no statistically significant difference in the change in ST according to knee flexion angle (Table 4).

The results of two-way ANOVA with repeated measures for ST on an unstable surface showed that there was no interaction according to whether there was visual deprivation or not or accrding to knee flexion angle. There was a statistically significant difference in the change in ST according to whether there was visual deprivation or not ($p<0.05$). But there was no statistically significant difference in the change in ST according to knee flexion angle (Table 5)

DISCUSSION

The body endlessly repeats the receiving and handling of various stimulations in order to adjust body balance during walking and in everyday living[17]. In order to maintain the

Table 2. Comparison of WDI according to whether there was visual deprivation or not or accrding to knee flexion angle on a stable surface

	Angle		
	0°	15°	30°
Posture with open eyes	5.17±2.23	5.35±3.17	4.29±2.55
Posture with closed eyes	5.31±2.04	4.85±1.96	5.08±1.82

Table 3. Comparison of WDI according to whether there was visual deprivation or not or according to knee flexion angle on an unstable surface

	Angle		
	0°	15°	30°
Posture with open eyes	3.54±1.51	6.09±2.27*	4.34±1.88*
Posture with closed eyes	4.34±2.17	4.85±2.99*	4.83±2.21*

Table 4. Comparison of ST according to whether there was visual deprivation or not or according to knee flexion angle on a stable surface

	Angle		
	0°	15°	30°
Posture with open eyes	15.44±7.07	14.61±5.32	14.57±3.87
Posture with closed eyes	20.46±12.47	17.66±4.72	19.97±4.92

Table 5. Comparison of ST according to whether there was visual deprivation or not or according to knee flexion angle on an unstable surface

	Angle		
	0°	15°	30°
Posture with open eyes	18.96±8.92	15.91±4.46	16.72±5.41
Posture with closed eyes	25.61±7.26	24.86±5.16	25.37±4.47

balance of the body, integration of infomation by the central nervous system and control of the musculoskeletal system, visual sense, vestibular organ, and proprioception are required. This study explored the change in balance ability in young adult females dependent on the angle of their knee joints in relation to the musculoskeletal system among the elements required to maintain balance.

Regarding the change in WDI dependent on the angle of knee flexion on a stable surface, the forward-facing posture with the eyes open exhibited a bigger change in body weight than the forward-facing posture with the eyes closed when the angle of knee flexion was 15°. When the angle of knee flexion was 30°, the forward-facing posture with the eyes closed exhibited a bigger change in body weight than the posture with the eyes open. But there was no interaction between knee flexion angle visual deprivation. Regarding the change in WDI dependent on the angle of knee flexion on an unstable surface, the posture with the eyes open exhibited a bigger change in body weight than the posture with the eyes closed when the angle of knee flexion was 15°. When the angle of knee flexion was 30°, the posture with the eyes closed exhibited a bigger change in body weight than the posture with eyes open. However, there was interaction between knee flexion angle and visual deprivation.

It has been reported that the proprioceptive sense of the knee joint works through the mechanical receptors in the joint, muscles, tendons, and related tissues. It has been also reported that proprioceptive sense is essential in controlling and vitalizing muscle and that it appropriatey controls the location and movement of the knee joint[18]. In their study on the change in balance ability dependent on visual deprivation with elderly individuals aged 85 years or older, Pyykö et al.[19] reported that the balance ability of their subjects decreased and that the visual sense accounted for approximately 50% of their postural control. It was possible to know based on previous literature that visual information is important with regard to the change in WDI dependent on the knee joint and that the change in WDI dependent on the change in the angle of knee flexion is bigger when visual information is deprived.

The change in stability index dependent on knee flexion increased by more in the posture with the eyes open than in the posture with the eyes closed on a stable plane. The change in stability index dependent on the angle of knee

flexion also increased by more in the posture with the eyes open than in the posture with the eyes closed on an unstable plane. There was no interaction dependent on the angle of knee flexion and the existence of visual deprivation both on a stable plane and an unstable plane; however, it was possible to see that the posture with the eyes open is statistically more stable than the posture with the eyes closed.

The knee joint can be easily damaged by supporting the body weight[20], and degenerative knee arthritis limits daily living through its symptoms of joint deformation and limitation of joint working range[21]. In particular, flexion contracture deformation occurs in lower limbs[22], and Kim[23] reported that hip joint bending, knee joint bending, and foot tip bending increase. In this study, an auxiliary device was used on the knee of normal adults in order to determine the change in stability index in postures used by knee arthritis patients. Choi[24] reported that the stability index of a patient group with serious cases of knee arthritis showed higher values for the stability index than a patient group with minor cases of knee arthritis after comparing the postural balance control capability between the two groups. Choi[24] said the reason for this was that the balance ability of the serious case patients was decreased by fatigue of the musculoskeletal system and a decrease in exercise capability of the lower limbs and spine. But there was no change in the stability index dependent on the angle of knee flexion in the present study. The reason for this is believed to be that he present study used normal adults as study subjects instead of knee arthritis patients.

The study results showed no change in both WDI and stability index dependent on the change in angle of knee flexion; however, the change in WDI increased when the angle of knee flexion increased while in the posture with the eyes closed. This study is limited in terms of sufficiently explaining the effects of knee joint angle on balance ability because the number of test subjects was small and there are not many previous studies on the knee joint with regard to balance ability. It is suggested that more studies on the knee joint with regard to balance ability should be done in the future with an increased number of test subjects and a wider variety of test subjects with musculoskeletal factors that have an impact on balance ability.

REFERENCES

1) Kwon BY: Effects of core stability and mobility training with aero equipment on biomechanical balance, posture, strength and agility for rhythmic gymnasts. Ewha Womans University Dissertation of Master's Degree, 2008.
2) Geurts AC, de Haart M, van Nes IJ, et al.: A review of standing balance recovery from stroke. Gait Posture, 2005, 22: 267–281. [Medline] [CrossRef]
3) Burl MM, Williams JG, Nayak US: Effects of cervical collars on standing balance. Arch Phys Med Rehabil, 1992, 73: 1181–1185. [Medline]
4) Kim HG: Effect of knee muscle power strengthening using thera band on the balance control ability in the elderly. DanKook University Dissertation of Master's Degree, 2003.
5) Nyberg L, Gustafson Y: Patient falls in stroke rehabilitation. A challenge to rehabilitation strategies. Stroke, 1995, 26: 838–842. [Medline] [CrossRef]
6) Cornwall MW, Murrell P: Postural sway following inversion sprain of the ankle. J Am Podiatr Med Assoc, 1991, 81: 243–247. [Medline]
7) Freeman MA: Instability of the foot after injuries to the lateral ligament of the ankle. J Bone Joint Surg Br, 1965, 47: 669–677. [Medline]
8) Grigg P, Finerman GA, Riley LH: Joint-position sense after total hip replacement. J Bone Joint Surg Am, 1973, 55: 1016–1025. [Medline]
9) Wegener L, Kisner C, Nichols D: Static and dynamic balance responses in persons with bilateral knee osteoarthritis. J Orthop Sports Phys Ther, 1997, 25: 13–18. [Medline]
10) Gardner MM, Robertson MC, Campbell AJ: Exercise in preventing falls and fall related injuries in older people: a review of randomised controlled trials. Br J Sports Med, 2000, 34: 7–17. [Medline] [CrossRef]
11) Barnett A, Smith B, Lord SR, et al.: Community-based group exercise improves balance and reduces falls in at-risk older people: a randomised controlled trial. Age Ageing, 2003, 32: 407–414. [Medline] [CrossRef]
12) Judge JO, Lindsey C, Underwood M, et al.: Balance improvements in older women: effects of exercise training. Phys Ther, 1993, 73: 254–262, discussion 63–65. [Medline]
13) Whipple RH, Wolfson LI, Amerman PM: The relationship of knee and ankle weakness to falls in nursing home residents: an isokinetic study. J Am Geriatr Soc, 1987, 35: 13–20. [Medline]
14) Ostrosky KM, VanSwearingen JM, Burdett RG, et al.: A comparison of gait characteristics in young and old subjects. Phys Ther, 1994, 74: 637–644, discussion 44–46. [Medline]
15) Kohen-Raz R, Kohen-Raz A, Erel J, et al.: Postural control in pilots and candidates for flight training. Aviat Space Environ Med, 1994, 65: 323–326. [Medline]
16) Kohen-Raz R: Application of tetra-ataxiametric posturography in clinical and developmental diagnosis. Percept Mot Skills, 1991, 73: 635–656. [Medline] [CrossRef]
17) Kim CR: Assessments of balance control using tetra-ataxiametric posturography. Ulsan University Dissertation of Doctorate Degree, 2010.
18) van der Esch M, Steultjens M, Harlaar J, et al.: Joint proprioception, muscle strength, and functional ability in patients with osteoarthritis of the knee. Arthritis Rheum, 2007, 57: 787–793. [Medline] [CrossRef]
19) Pyykkö I, Jantti P, Aalto H: Postural control in elderly subjects. Age Ageing, 1990, 19: 215–221. [Medline] [CrossRef]
20) Heiden TL, Lloyd DG, Ackland TR: Knee joint kinematics, kinetics and muscle co-contraction in knee osteoarthritis patient gait. Clin Biomech (Bristol, Avon), 2009, 24: 833–841. [Medline] [CrossRef]
21) Miyaguchi M, Kobayashi A, Kadoya Y, et al.: Biochemical change in joint fluid after isometric quadriceps exercise for patients with osteoarthritis of the knee. Osteoarthritis Cartilage, 2003, 11: 252–259. [Medline] [CrossRef]
22) Astephen JL, Deluzio KJ, Caldwell GE, et al.: Biomechanical changes at the hip, knee, and ankle joints during gait are associated with knee osteoarthritis severity. J Orthop Res, 2008, 26: 332–341. [Medline] [CrossRef]
23) Kim DM: The biomechanical changes of lower extremities and factors affecting knee joint during gait in subjects with degenerative knee osteoarthritis. Korea University Dissertation of Master's Degree, 2010.
24) Choi SH: Balance control according to the severity of knee osteoarthritis. Kyunghee University Dissertation of Doctorate Degree, 2011.