MEDICAL SCIENCE MONITOR

CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2018; 24: 3168-3175
DOI: 10.12659/MSM.908260

Received: 2017.11.28
Accepted: 2017.12.07
Published: 2018.05.15

Effect of Ankle Range of Motion (ROM) and Lower-Extremity Muscle Strength on Static Balance Control Ability in Young Adults: A Regression Analysis

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEF 1 **Seong-Gil Kim**
ABCDEF 2 **Wan-Soo Kim**

1 Department of Physical Therapy, Uiduk University, Gyeongju, Gyeongbuk, Republic of Korea
2 Department of Rehabilitation and Health Promotion, College of Rehabilitation Sciences, Daegu University, Gyeongsan, Gyeongbuk, Republic of Korea

Corresponding Author: Wan-Soo Kim, e-mail: wsk115@daegu.ac.kr
Source of support: Departmental sources

Background: The purpose of this study was to investigate the effect of ankle ROM and lower-extremity muscle strength on static balance control ability in young adults.

Material/Methods: This study was conducted with 65 young adults, but 10 young adults dropped out during the measurement, so 55 young adults (male: 19, female: 36) completed the study. Postural sway (length and velocity) was measured with eyes open and closed, and ankle ROM (AROM and PROM of dorsiflexion and plantarflexion) and lower-extremity muscle strength (flexor and extensor of hip, knee, and ankle joint) were measured. Pearson correlation coefficient was used to examine the correlation between variables and static balance ability. Simple linear regression analysis and multiple linear regression analysis were used to examine the effect of variables on static balance ability.

Results: In correlation analysis, plantarflexion ROM (AROM and PROM) and lower-extremity muscle strength (except hip extensor) were significantly correlated with postural sway ($p<0.05$).
In simple correlation analysis, all variables that passed the correlation analysis procedure had significant influence ($p<0.05$). In multiple linear regression analysis, plantar flexion PROM with eyes open significantly influenced sway length (B=0.681) and sway velocity (B=0.011).

Conclusions: Lower-extremity muscle strength and ankle plantarflexion ROM influenced static balance control ability, with ankle plantarflexion PROM showing the greatest influence. Therefore, both contractile structures and non-contractile structures should be of interest when considering static balance control ability improvement.

MeSH Keywords: **Ankle Joint • Muscle Strength Dynamometer • Postural Balance • Range of Motion, Articular • Regression Analysis**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/908260

3493 5 1 26

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Background

Balance ability refers to the ability to maintain the center of gravity above the base of support and to keep stable body alignment and posture [1]. Balance control ability can be divided into dynamic balance control ability and static balance control ability according to the movement. Dynamic balance control ability controls balance of the body during movement such as walking, and static balance control ability controls balance of the body while standing still [2,3]. Because these 2 balance control abilities are applied differently depending on the situation, the patterns and strategies of using the joints are also different [2–5].

Because the human center of gravity (COG) is high, dynamic balance control ability and static balance control both require considerable energy consumption and high levels of motor control [6]. Previous studies on static balance control ability showed that leg strength, ROM, proprioception, and joint stability are related to static balance ability.

To maintain upright posture, a certain level of muscle strength is essential, and lower-extremity muscles near the ankle and knee joint must work properly to maintain posture stability and prevent falls [5,7].

Ankle joint ROM is also important, because balance is most frequently controlled in the ankle joint, and the movement of the joint is large [8–10]. In addition, the proprioception that senses the position of the joints and the stiffness of the non-contractile structures around the joints, which are related to joint stability, can also affect static balance control ability [6,7,11,12].

Factors affecting balance ability have been studied for many years [5,7–10,13]. However, there is little information on how these factors affect static balance ability and how these influences appear when these factors are combined. Therefore, we performed the present study to investigate the effect of ankle ROM and lower-extremity muscle strength, and to determine which factors have the greatest effect on static balance ability. Therefore, the purpose of this study was to analyze the effect of ankle ROM and lower-extremity muscle strength on static balance control ability in young adults.

Material and Methods

Subjects

We attempted to enroll 70 young adults attending U University in Gyeongsangbuk-do Province, but 5 people refused; therefore, this study was conducted with 65 young adults. However, 10 people dropped out during the measurement period, so 55 young adults (male: 19, female: 36) completed the study. The mean age was 19.85±1.25 years, mean height was 165.62±7.93 cm, and mean body weight was 60.04±12.16 kg (Table 1). We excluded persons with a specific disease that would affect the study, visual or auditory impairment, nervous system or vestibular problems, or who could not understand the experiment. In accordance with the Helsinki Declaration of Ethics, all subjects prior to the experiment were briefed on the purpose and procedure of the study and voluntarily agreed to take part. The study was approved by the Institutional Review Board of Daegu University (No. 1040621-201411-HR-009-02).

Table 1. General subject characteristics (n=55).

Variable	Mean ±SD
Age (year)	19.85±1.25
Height (cm)	165.62±7.93
Weight (kg)	60.04±12.16
Sex (Male/Female)	19/36

SD – standard deviation.

Study protocol

Before the experiments, all subjects were informed about the experimental methods and procedures, which were demonstrated by one of the researchers before the test.

To prevent fatigue of lower-extremity muscles from affecting other measurement results, the measurement order was fixed. After measuring the balance ability for the first time, ankle ROM was measured and leg strength was measured at the end. Balance ability was measured by keeping the subject on the balance board and measuring the sway length and sway velocity for 1 min. This performance was measured with eyes closed and then with eyes open.

Ankle ROM was measured in dorsiflexion and plantar flexion, and both active and passive ROM were measured. Muscle strength was measured by measuring the flexor and extensor of the 3 joints of the lower extremities (hip joint, knee joint, and ankle joint) and evaluating quantitative values using a muscle contraction dynamometer. Patients were given sufficient rest between measurements to avoid fatigue, and ROM and muscle strength measurements were measured by 2 therapists. After all the measurements were taken during the day, the subjects were scheduled for another day to make repeated measurements (Figure 1). All measurements were performed 3 times and the results are expressed as mean ± standard deviation.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

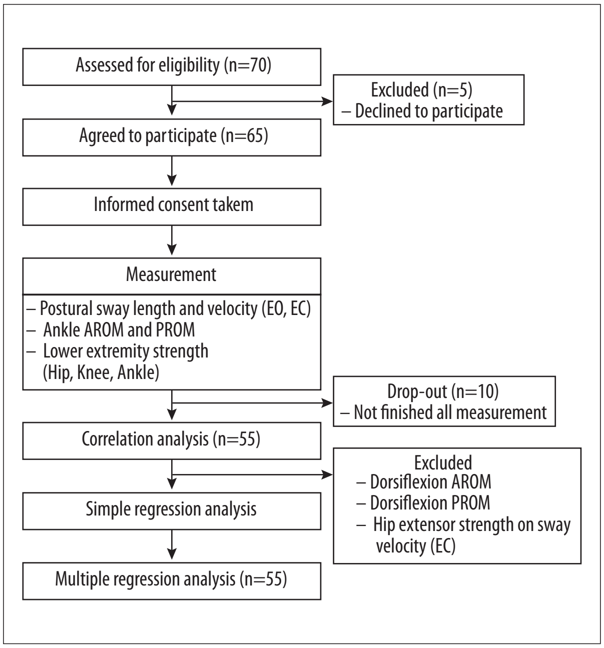

Figure 1. Study flowchart. EO – eyes open; EC – eyes closed; AROM – active range of motion; PROM – passive range of motion.

Lower-extremity strength

A hand-held dynamometer (Commander Muscle Tester, JTech, USA) was used to evaluate the lower-extremity strength of the subjects. Evaluation of muscle strength using the hand-held dynamometer is performed in the same manner as the manual muscle strength test, but it is more advantageous and more objective than the manual test in detecting a change in muscle strength because the specific numerical value of muscle strength is shown [14].

All subjects were measured for muscle strength in 6 groups of the lower extremities (extensors and flexors of ankle, knee, and hip joint).

As for the measurement postures, the dorsiflexors and plantar flexors of the ankle and flexors and extensors of the hip joints were measured in supine position, and flexors and extensors of the knee joint were measured in sitting position. The measurement of muscle strength was performed in the order of the dorsiflexors and plantar flexors of the ankle, flexors and extensors of the hip joints, and flexors and extensors of the knee joint. A break between the measurements was provided to prevent muscle weakness due to muscle relaxation [15].

Postural balance

The Bio-Rescue (RM Ingenierie) device was used to measure balance ability. The Bio-Rescue has a 610×580×10 mm platform and a total of 1600 pressure sensors. With these sensors, the moving distance and speed of the body's center of pressure (COP) can be measured while the subject is in position, thereby evaluating static balance ability. Dynamic balance ability can also be assessed through the limits of stability (LOS) of the COP movement just before the subject loses balance. It also has various training programs, so it can be used to improve balance ability [13,16].

The present study measured static balance ability. Subjects were placed on the Bio-Rescue pads with their feet extended to the shoulder width, and then sway length and sway velocity were measured by tracing the moving distance of the body center for 1 min. This performance was measured when the eyes were open and visual information was provided, and then when both eyes were closed and the visual information was blocked.

Ankle range of motion

Ankle ROM, which has the greatest influence on static balance ability, was measured using a manual goniometer, and dorsiflexion and plantarflexion of the ankle joint were measured.

Measuring joint ROM with a goniometer has been performed by therapists for many years and has a high degree of reliability [17,18].

In sitting position, the angle of movement was measured at the neutral position of the ankle, and both active and passive ROM were measured. For active ROM, the angle is measured at the maximum extent. For the passive ROM, the subject kept still and was manually measured by moving the subject to the end range. The measurement axis was set to lateral malleolus. While measuring, the fixed arm was parallel to the outside of the calf and the moving arm was parallel to the outer line of the 5th metatarsal bone.

Statistical analysis

SPSS for Windows (version 22.0) was used to analyze data. Descriptive statistics were used to determine the general characteristics of the subjects. Pearson correlation coefficient was used to examine the correlation between variables and static balance ability. Simple linear regression analysis and multiple linear regression analysis were used to examine the effect of variables on static balance ability.

Before performing multiple linear regression analysis, Pearson correlation coefficients and simple linear regression analysis were used to select variables for multiple regression analysis. Statistical significance level was set at α=.05.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 2. Correlation between ankle ROM and balance ability (n=55).

		AROM Dorsiflexion (angle)	AROM Plantarflexion (angle)	PROM Dorsiflexion (angle)	PROM Plantarflexion (angle)
		11.49±4.43	**62.45±8.79**	**16.05±5.98**	**70.04±7.70**
Sway length EO (cm)	36.97±7.32[a]	–0.015	0.325*	0.002	0.525**
Sway length EC (cm)	45.84±7.78	–0.022	0.312*	–0.026	0.440**
Sway velocity EO (cm/s)	0.61±0.12	0.017	0.274*	0.027	0.467**
Sway velocity EC (cm/s)	0.76±0.13	–0.001	0.281*	–0.019	0.431**

Mean ±SD [a]; * p<.05; ** p<.01; EO – eyes open; EC – eyes closed; AROM – active range of motion; PROM – passive range of motion.

Results

Correlation between ankle ROM and balance ability

Sway length had a significant positive correlation with plantar flexion AROM and PROM.

With eyes open, sway length had a significant positive correlation with plantar flexion AROM (r=0.325) and plantar flexion PROM (r=0.525) (P<0.05). With eyes closed, sway length had a significant positive correlation with plantar flexion AROM (r=0.312) and plantar flexion PROM (r=0.440) (P<0.05). Sway velocity had a significant positive correlation with plantar flexion AROM and PROM. With eyes open, sway velocity had a significant positive correlation with plantar flexion AROM (r=0.274) and plantar flexion PROM (r=0.467) (P<0.05). With eyes closed, sway velocity had a significant positive correlation with plantar flexion AROM (r=0.281) and plantar flexion PROM (r=0.431) (P<0.05) (Table 2).

Correlation between lower-extremity muscle strength and balance ability

Sway length had a significant negative correlation with lower-extremity muscle strength.

With eyes open, sway length had a significant negative correlation with ankle dorsiflexor (r=–0.402), ankle plantarflexor (r=–0.369), knee flexor (r=–0.340), knee extensor (r=–0.395), hip flexor (r=–0.299), and hip extensor (r=–0.306) (P<0.05). With eyes closed, sway length had a significant negative correlation with ankle dorsiflexor (r=–0.427), ankle plantarflexor (r=–0.387), knee flexor (r=–0.316), knee extensor (r=–0.374), Hip flexor (r=–0.284), and hip extensor (r=–0.270) (P<0.05). Sway velocity had a significant negative correlation with all other lower-extremity muscle strengths except the hip extensor with closed eyes. With eyes open, sway velocity had a significant negative correlation with ankle dorsiflexor (r=–0.337), ankle plantarflexor (r=–0.339), knee flexor (r=–0.310), knee extensor (r=–0.369), hip flexor (r=–0.269), and hip extensor (r=–0.275) (P<0.05). With eyes closed, sway velocity had a significant negative correlation with ankle dorsiflexor (r=–0.442), ankle plantarflexor (r=–0.391), knee flexor (r=–0.311), knee extensor (r=–0.385), and hip flexor (r=–0.303) (P<0.05) (Table 3).

Simple linear regression analysis of each variable for sway length and velocity

Simple linear regression analysis was performed using only variables with significant correlation with sway length and velocity. With eyes open, sway length was significantly influenced by AROM and PROM of the plantar flexion and each lower-extremity muscle strength (P<0.05). With eyes open, sway velocity was significantly influenced by AROM and PROM of the plantar flexion and muscle strength in each lower extremity (P<0.05) (Table 4).

With eyes closed, sway length sway length was significantly influenced by AROM and PROM of the plantar flexion and muscle strength in each lower extremity (P<0.05). With eyes closed, sway velocity was significantly influenced by AROM and PROM of the plantar flexion (P<0.05). With eyes closed, sway length was significantly influenced by all other muscles except the hip extensor strength (Table 4).

Multiple linear regression analysis of sway length and velocity

Simple linear regression analysis was performed using only variables with significant correlation with sway length and velocity. After performing simple linear regression analysis, significant variables were collected and multiple regression analysis was performed. With eyes open, the sway length was significantly influenced by plantar flexion PROM (B=0.681, P<0.05). The sway velocity was also significantly affected by plantar flexion PROM (B=0.011, P<0.05) (Table 5).

With eyes closed, the plantar flexion PROM is the closest to the significance level, as was the case with eye open. However, there were no variables other than constants that significantly affected sway length and sway velocity (P>0.05) (Table 5).

Table 3. Correlation between lower extremity muscle strength and balance ability (n=55).

		MAD (kg)	MAP (kg)	MKF (kg)	MKE (kg)	MHF (kg)	MHE (kg)
		11.21±4.09	13.78±5.21	10.70±4.55	15.21±6.79	16.03±6.44	12.51±4.79
Sway length EO (cm)	36.97±7.32[a]	−0.402**	−0.369**	−0.340*	−0.395**	−0.299*	−0.306*
Sway length EC (cm)	45.84±7.78	−0.427**	−0.387**	−0.316*	−0.374**	−0.284*	−0.270*
Sway velocity EO (cm/s)	0.61±0.12	−0.337*	−0.339*	−0.310*	−0.369**	−0.269*	−0.275*
Sway velocity EC (cm/s)	0.76±0.13	−0.442**	−0.391**	−0.311*	−0.385**	−0.303*	−0.251

Mean ±SD [a]; * p<.05; ** p<.01; EO – eye open; EC – eye close; MAD – muscle strength of ankle dorsiflexor; MAP – muscle strength of ankle plantar flexor; MKF – muscle strength of knee flexor; MKE – muscle strength of knee extensor; MHF – muscle strength of hip flexor; MHE – muscle strength of hip extensor.

Table 4. Simple linear regression analysis of each variable for sway length and velocity (n=55).

	Sway length EO		Sway length EC		Sway velocity EO		Sway velocity EC	
	R^2	Significance (p)	R^2	Significance (p)	R^2	Significance (p)	R^2	Significance (p)
AROM plantarflexion	0.106	0.015*	0.097	0.020*	0.075	0.043*	0.079	0.038*
PROM plantarflexion	0.275	0.000**	0.194	0.001**	0.218	0.000**	0.186	0.001**
MAD	0.162	0.002**	0.183	0.001**	0.113	0.012*	0.195	0.001**
MAP	0.136	0.006**	0.150	0.004**	0.115	0.011*	0.153	0.003**
MKF	0.116	0.011*	0.100	0.019*	0.096	0.021*	0.097	0.021*
MKE	0.156	0.003**	0.140	0.005*	0.136	0.006**	0.148	0.004**
MHF	0.089	0.027*	0.080	0.036*	0.072	0.047*	0.092	0.024*
MHE	0.094	0.023*	0.073	0.047*	0.076	0.042*	0.063	0.064

* p<.05; ** p<.01; EO – eye open; EC – eye close; AROM – active range of motion; PROM – passive range of motion; MAD – muscle strength of ankle dorsiflexor; MAP – muscle strength of ankle plantar flexor; MKF – muscle strength of knee flexor; MKE – muscle strength of knee extensor; MHF – muscle strength of hip flexor; MHE – muscle strength of hip extensor.

Discussion

This study examined the effect of ankle ROM and lower-extremity muscle strength on static balance ability. Many researches have shown that lower-extremity muscle strength and ankle ROM affect balance ability. To investigate the effect of these factors on balance ability, we used multiple regression analysis. Pearson correlation coefficients and simple linear regression analysis were performed before multiple regression analysis.

First, the correlation between static balance ability and muscle strength and ROM variables was investigated through Pearson correlation coefficient analysis, and unrelated variables were deleted. Simple linear regression analysis was performed by collecting variables with significant correlations. Through simple linear regression analysis, only the variables that significantly affect static balance ability were selected and the non-significant variables were deleted. The variables that passed these 2 processes were collected again and multiple regression analysis was performed.

In the analysis of correlation between ankle ROM and balance ability, plantar flexion AROM and plantar flexion PROM showed a positive correlation with balance ability variables (sway length EO and EC, sway velocity EO and EC). Correlation coefficients with PROM were slightly higher than with AROM. Mecagni et al. found the greatest correlation between balance ability and inversion, followed by dorsiflexion ROM and plantar flexion ROM [8]; their conclusion that balance ability is correlated with plantar flexion is consistent with results of the present study. However, their finding that increased plantar flexion ROM has a positive relationship with balance ability disagrees with our results.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 5. Multiple linear regression analysis of sway length and velocity (n=55).

	Sway length EO		Sway length EC		Sway velocity EO		Sway velocity EC	
	B	Significance (p)	B	Significance (p)	B	Significance (p)	B	Significance (p)
Constant	14.494	0.180	33.231	0.008**	0.270	0.153	0.577	0.004**
AROM plantarflexion	−0.326	0.072	−0.184	0.360	−0.006	0.061	−0.004	0.237
PROM plantarflexion	0.681	0.002**	0.440	0.071	0.011	0.004**	0.008	0.051
MAD	−0.073	0.696	−0.223	0.289	0.001	0.856	−0.004	0.272
MAP	−0.136	0.393	−0.172	0.337	−0.003	0.275	−0.003	0.348
MKF	−0.183	0.328	−0.142	0.500	−0.003	0.426	−0.001	0.712
MKE	−0.131	0.305	−0.133	0.353	−0.003	0.238	−0.002	0.329
MHF	0.313	0.092	0.345	0.100	0.005	0.116	0.005	0.131
MHE	−0.047	0.737	−0.010	0.947	−0.001	0.755		
	R^2=0.394, F=3.733 (p=0.002)		R^2=0.315, F=2.649 (p=0.018)		R^2=0.338, F=2.937 (p=0.010)		R^2=0.313, F=3.058 (p=0.010)	

* p<.05; ** p<.01; EO – eye open; EC – eye close; AROM – active range of motion; PROM – passive range of motion; MAD – muscle strength of ankle dorsiflexor; MAP – muscle strength of ankle plantar flexor; MKF – muscle strength of knee flexor; MKE – muscle strength of knee extensor; MHF – muscle strength of hip flexor; MHE – muscle strength of hip extensor.

The use of FRT to assess balance ability in the previous study differed from the present study. Both are tests to measure balance ability, but in the sway length test the subject tries to not move, while in the FRT the subject moves forward to the maximum. Therefore, FRT should be more affected by contractile structures. However, the postural sway test is more static, so it is affected by relatively non-contractile structures (such as ligaments). The results of the 2 studies are different because they used different tests.

Spink et al. investigated the relationship between ankle ROM and sway length in the elderly, and their result that dorsiflexion ROM is not related to sway length is consistent with our results [9]. However, the results for plantarflexion cannot be compared because ROM was measured only for dorsiflexion (plantarflexion ROM was not measured) in their study.

In the study by Bok et al., which investigated the relationship between ankle ROM and balance ability for young adults and the elderly, sway was increased as the ROM of the dorsiflexion increased in the elderly, but there was no correlation between the ankle ROM and sway in the younger adults [10].

The previous studies examining the correlation between ankle ROM and sway were mainly conducted on the elderly. Even these studies focused primarily on dosrification, and there have been few studies on plantarflexion [1,8,19]. These studies suggest that the diminished balance control ability of the elderly is caused by the dorsiflexion ROM limitation due to the shortening of the ankle surrounding tissues because of aging [1,8,19,20]. However, there have also been studies that show contradictory results. Han et al. reported that sway length and velocity in the elderly increased after plantarflexor stretching in the dorsiflexion direction [13]. Lima et al. found that young adults showed an increase in the passive range of motion of the ankle dorsiflexion after plantarflexor stretching, but postural sway also increased [21].

Thus, an increase in dorsiflexion ROM does not always have a positive effect on balance ability, and there may be a negative relationship.

Balance control ability and ROM are best in the normal range. When the ROM is limited, the ROM is positively correlated with balance control ability. However, when the ROM range is too large and the joint is loosened, ROM is negatively correlated with balance control ability [19,20].

In the present study, dorsiflexion had no significant correlation but plantarflexion ROM was positively correlated with sway length and velocity. Looking at the ROM range of the subjects, the range of plantarflexion is slightly larger than the normal range [22], which suggests that the structures in front of the ankle are slightly loose. This suggests that plantarflexion ROM has a negative relationship with balance control ability.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

In the present study, except for the hip joint extensor, the muscle strength of the remaining muscles was negatively correlated with the balance ability variables (sway length EO and EC, sway velocity EO and EC). These results indicate that greater lower-extremity muscle strength is associated with less postural sway and better balance control ability. This is well known, and many previous studies reported results consistent with these findings. Laughton et al. reported that a decrease in lower-extremity muscle strength increased postural sway [23] and Kligytė et al. also reported that a decrease in muscle strength reduced balance control ability [24]. Shumway-Cook et al. found that a certain level of lower-extremity muscle strength is essential for balance control, and coordination of the lower-extremity muscles maintains posture stability and prevents falls [5]. Thus, in a standing posture, lower-extremity muscle strength is an important variable for balance control, and increased muscle strength improves balance control ability.

For the results of the correlation coefficient (r), ankle joint had higher correlation with postural sway than other joints, and dorsiflexor was the most correlated.

Aoyama et al. reported that knee and hip joints were used more frequently than ankle joint when sudden postural changes occurred in a standing posture. However, the ankle joint was used more often than other joints when standing still and controlling the balance [4].

Ankle joints are preferred over other muscles for static postural control. When the ankle joint is in a range that cannot be accommodated, hip joints are used to prevent falls, increasing postural sway [5]. In particular, dorsiflexion strength has a higher correlation with postural sway than other muscles since ankle dorsiflexor eccentric control is frequently used during postural control in standing position [7].

A simple linear regression analysis was performed on the variables that showed a significant correlation with balance ability variables. The variables that had a significant correlation with balance ability were also significant in the simple linear regression analysis, suggesting that the variables significantly correlated with balance ability have some influence on balance ability.

Multiple regression analysis was performed by collecting the variables that passed the above procedure, showing different results depending on the presence of visual information.

Previous studies related to sway according to the presence of visual information showed that sway is larger when the subject does not have visual information. In this study, sway length and velocity were larger when there was no visual information, which was consistent with previous studies [9,25]. However, the effect on sway had different results.

Plantarflexion PROM had the most effect on sway length and sway velocity with the eyes open. The p value of plantarflexion PROM was close to the 0.05 level with eyes closed, but was not significant. In other words, there were no significant influencing variables.

Gatev et al. reported that when posture is controlled while standing still, postural control is performed through feedforward if visual information is given, but posture is controlled through feedback if there is no visual information. Feedforward is more frequent than feedback in attempting to balance control using muscles at a higher level than feedback. The use of the muscles around the ankle and the load are greater because the number of times action is needed to control the posture is relatively higher than the feedback [6].

As the visual information is given and the number of attempts to control the balance using the ankle muscles through the feedforward increases, the role of the structures that stabilize the ankle by holding it manually will become greater. However, since feedback modifies posture after balance is lost, the number muscles used for posture control will be small and the role of non-contractile structures will be relatively small. In our study, with eyes closed, the result was close to the significance level, but was not significant because of these small differences.

In a study by Wang et al., there was no difference between an injured leg and an uninjured leg when ankle joint muscle strength was measured after recovery. However, when postural sway was measured, the sway length was further increased in the injured leg. This result suggests that even if the contractile structures are restored, the balance control ability is weakened when the non-contractile structures and sensory organs are weakened [11].

AROM is influenced by muscles and tendons, which are contractile structures, and PROM is influenced by passive resistive torque of non-contractile structures of the ankle [20]. For this reason, the increase in PROM over a certain level means that the non-constrictive structures are loosened or stretched [12,26].

The increase of the PROM over a certain level indicates the loosening of the non-contractile structures, and thus the contractile structures have a negative influence on the balance control. In particular, the balance control in a standing position is more affected by stiffness of non-contractile structure than dynamic balance control is because it is greatly affected by structural stability in the ankle [6,20]. Some previous studies reported that the sway length was increased after training to increase the ROM of the plantar flexor [13,21].

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Conclusions

In conclusion, the static balance control ability when standing still in young adults is correlated with ankle ROM and lower-extremity muscle strength. Postural control in standing position can be considered to be influenced by both the lower-extremity muscle strength, which reflects the function of the contractile structure, and the ROM, which reflects the state of the non-contractile structures that serve to stabilize the ankle joint. In particular, it is mainly affected by plantarflexion PROM. The results of this study will be helpful clinically as basic data that can attract attention to non-contractile structures as well as contractile structures considering the static balance ability improvement. The limitation of this study is that ROM was measured only in the sagittal plane, and inversion and eversion should be assessed in future studies.

Conflict of interest

None.

References:

1. Horak FB: Clinical measurement of postural control in adults. Phys Ther, 1987; 67(12): 1881–85
2. Winter DA, Patla AE, Frank JS: Assessment of balance control in humans. Med Prog Technol, 1990; 16(1–2): 31–51
3. Bressel E, Yonker JC, Kras J, Heath EM: Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. J Athl Train, 2007; 42(1): 42–46
4. Aoyama M, Suzuki Y, Onishi J, Kuzuya M: Physical and functional factors in activities of daily living that predict falls in community-dwelling older women. Geriatr Gerontol Int, 2011; 11(3): 348–57
5. Shumway-Cook A, Woollacott MH: Motor control: Theory and practical applications. 2nd ed. Baltimore: Williams & Wilkins; 2001; 172–76
6. Gatev P, Thomas S, Kepple T, Hallett M: Feedforward ankle strategy of balance during quiet stance in adults. J Physiol, 1999; 514(3): 915–28
7. Lord SR, Clark RD, Webster IW: Postural stability and associated physiological factors in a population of aged persons. J Gerontol, 1991; 46(3): 69–76
8. Mecagni C, Smith JP, Roberts KE, O'Sullivan SB: Balance and ankle range of motion in community-dwelling women aged 64 to 87 years: A correlational study. Phys Ther, 2000; 80(10): 1004–11
9. Spink MJ, Fotoohabadi MR, Wee E et al: Foot and ankle strength, range of motion, posture, and deformity are associated with balance and functional ability in older adults. Arch Phys Med Rehabil, 2011; 92(1): 68–75
10. Bok S-K, Lee TH, Lee SS: The effects of changes of ankle strength and range of motion according to aging on balance. Ann Rehabil Med, 2013; 37(1): 10–16
11. Wang H-K, Chen C-H, Shiang T-Y, Jan M-H, Lin K-H: Risk-factor analysis of high school basketball–player ankle injuries: A prospective controlled cohort study evaluating postural sway, ankle strength, and flexibility. Arch Phys Med Rehabil, 2006; 87(6): 821–25
12. Vandervoort AA, Chesworth BM, Cunningham DA, Paterson DH et al: Age and sex effects on mobility of the human ankle. J Gerontol, 1992; 47(1): 17–21
13. Han M-J, Yuk G-C, Gak H et al: Acute effects of 5 min of plantar flexor static stretching on balance and gait in the elderly. J Phys Ther Sci, 2014; 26(1): 131–33
14. Bohannon RW, Andrews AW: Interrater reliability of hand-held dynamometry. Phys Ther, 1987; 67(6): 931–33
15. Bohannon RW: Test-retest reliability of hand-held dynamometry during a single session of strength assessment. Phys Ther, 1986; 66(2): 206–9
16. Kim S-G, Lee J-H: The effects of horse riding simulation exercise on muscle activation and limits of stability in the elderly. Arch Gerontol Geriatr, 2015; 60(1): 62–65
17. Pua Y-H, Wrigley TW, Cowan SM, Bennell KL: Intrarater test-retest reliability of hip range of motion and hip muscle strength measurements in persons with hip osteoarthritis. Arch Phys Med Rehabil, 2008; 89(6): 1146–54
18. Kim S-G, Kim E-K: Test-retest reliability of an active range of motion test for the shoulder and hip joints by unskilled examiners using a manual goniometer. J Phys Ther Sci, 2016; 28(3): 722–24
19. Gajdosik RL, Vander Linden DW, Williams AK: Influence of age on length and passive elastic stiffness characteristics of the calf muscle-tendon unit of women. Phys Ther, 1999; 79(9): 827–38
20. Loram ID, Maganaris CN, Lakie M: The passive, human calf muscles in relation to standing: The non-linear decrease from short range to long range stiffness. J Physiol, 2007; 584(2): 661–75
21. Lima BN, Lucareli PR, Gomes WA et al: The acute effects of unilateral ankle plantar flexors static-stretching on postural sway and gastrocnemius muscle activity during single-leg balance tasks. J Sports Sci Med, 2014; 13(3): 564–70
22. Boone DC, Azen SP: Normal range of motion of joints in male subjects. J Bone Joint Surg Am, 1979; 61(5): 756–59
23. Laughton CA, Slavin M, Katdare K, Nolan L, Bean JF, Kerrigan DC et al: Aging, muscle activity, and balance control: Physiologic changes associated with balance impairment. Gait Posture, 2003; 18(2): 101–8
24. Kligyte I, Lundy-Ekman L, Medeiros JM: Relationship between lower extremity muscle strength and dynamic balance in people post-stroke. Medicina (Kaunas), 2003; 39(2): 122–28
25. Giagazoglou P, Amiridis IG, Zafeiridis A et al: Static balance control and lower limb strength in blind and sighted women. Eur J Appl Physiol, 2009; 107(5): 571–79
26. Gajdosik RL, Bohannon RW: Clinical measurement of range of motion: Review of goniometry emphasizing reliability and validity. Phys Ther, 1987; 67(12): 1867–72

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]