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Comparison of Center of Pressure Displacement during Sit to Stand to Sit and Balance Ability of Subjects with and without Chronic Ankle Instability

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Abstract

Purpose : The purpose of this study is to compare the balance ability between subjects with chronic ankle instability and normal people and the center of pressure displacement during the sit to stand and stand to sit.

Methods : The subjects of this study were 63 who met the inclusion criteria and were classified into normal group (n=33) and chronic ankle instability group (n=30). The displacement of the center of pressure during sit to stand and stand to sit was measured. And the limit of stability and Y-balance tests were performed to measure the balance ability. Independent t-test was conducted to compare center of pressure displacement and balance ability between groups, and pearson correlation was conducted to analyze the correlation between the center of pressure displacement and balance ability.

Results : In the case of the center of pressure displacement, there was a significant difference between the two groups during sit to stand and stand to sit. In the case of balance, both limit of stability and Y-balance test showed significant differences between the two groups. At the time of sit to stand, the center of pressure displacement showed a significant correlation with balance abilities, and at the time of stand to sit, the center of pressure displacement showed a significant correlation with Y-balance test.

Conclusion : Chronic ankle instability shows that there is a lot of sway in the body due to compensation to replace the decrease in ankle joint range of motion when performing sit to stand and stand to sit due to sensory input damage such as decrease in ankle range of motion and decrease in ankle proprioception. Chronic ankle instability is expected to have a negative effect on our daily lives in life. The results of this study will serve as the basis for the dynamic approach to objective evaluation, treatment, and prevention of chronic ankle instability.

Key Words : balance, center of pressure, chronic ankle instability, sit to stand, stand to sit

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Ⅰ. Introduction

Ankle joints are the most frequently damaged joints during daily life activities when the foot touches a sudden change of direction and stop or unexpected place (Gilbreath et al., 2014). Among the various injuries, ankle sprains can often occur during sports activities or daily life, of which 90 % is caused by inversion, resulting in damage to the lateral ligaments of the ankle during excessive inversion, resulting in hypermobility or loss of balance (Basnett et al., 2013). Repeated occurrences of such ligament damage are accompanied by subjective instability, edema, and inflammation, which are called chronic ankle instability (CAI) (Basnett et al., 2013).

CAI suffers from insufficient rehabilitation after sprained ankle, resulting in muscle weakness, reduced balance and coordination, and repeated damage (Kim & Sung, 2018).

CAI-induced decline in posture control increases the risk of falls during daily life, and the structure of the ankle joint itself is impaired, negatively affecting the body during functional movements (Lee et al., 2020). In particular, sit to stand (SitTS) and stand to sit (StandTS), which are essential movements to perform functional activities during daily life, are so frequent in our daily lives that they repeat more than 60 times a day on average (Millor et al., 2014). This movement is one of the most commonly used movements in everyday life, a necessary prerequisite for independent and basic functions such as stair climbing, lifting and moving objects, and walking, and an indicator of functional ability (Millor et al., 2014). In addition, unstable postural control during StandTS performance causes falls, and starting postures such as the execution speed of movement and dorsiflexion of the ankle joint during SitTS and StandTS performance create differences in kinematics and dynamic variables (Ejupi et al., 2016).

Postural control is important to perform SitTS and StandTS (Millor et al., 2014). Postural control refers to the ability to maintain center of gravity in a minimum postural sway within the base of support when maintaining a static posture, moving, or reacting to an external force (Tasseel-Ponche et al., 2015). Research on CAI has been conducted on chronic ankle instability by using pedobargraph to find out the relationship between center of pressure (COP) and CAI, to analyze muscle strength and balance of ankle instability subjects and to evaluate muscle activity and foot pressure tests during walking, to compare and use Cumberland ankle instability tool (CAIT) (Kim et al., 2013; Lee et al., 2018; Park et al., 2020). The CAIT is the first evaluation tool to score the degree of ankle instability and consists of 9 questions. A score of 28 or more out of a total score of 30 is considered normal, and a score of 24 or less is defined as ankle instability (Kim et al., 2013). Furthermore, previous studies concluded that CAI subjects were more affected by temporal variables and gait variability than normal people when dual tasks were given to subjects who complained of CAI, and presented as the basis for the CAI subjects' adaptability to the sensory motor system being lower than normal people (Cha & Park, 2017).

If musculoskeletal damage occurs in the ankle joint, ankle proprioception, positional sensation, and muscle strength are deteriorated (Xue et al., 2021). A weakened muscle gradually causes ankle joint failure, resulting in muscle fatigue around the weakened ankle joint during physical activity, which greatly shifts the center of foot pressure and reduces static and dynamic stability, resulting in an increased risk of redamage (Lee et al., 2018).

Although many studies have been conducted on motion analysis based on balance and foot pressure for CAI, studies analyzing posture control ability during SitTS and StandTS are insufficient. In addition to the existing evaluation, the measurement of postural control ability during SitTS and StandTS will contribute to increasing the understanding of the biomechanical mechanism and kinematic analysis of CAI through a comprehensive evaluation of CAI, and consequently have a positive effect on the evaluation of CAI and the development of suitable

exercises.

The purpose of this study is to compare the center of pressure displacement during the SitTS and StandTS and balance ability between subjects with CAI and normal people.

Ⅱ. Methods

1. Subjects

This study was conducted as a subject who met the inclusion criteria among those who expressed their intention to voluntarily participate by sufficiently listening and agreeing to the purpose and method of research. In the case of the CAI group, those who have suffered at least one ankle sprain injury in the past, experienced at least two ankle hypermobility symptoms within the last three months, and scored less than 24 points during CAIT. In the case of the normal group, those who have never experienced ankle pain in the past and do not have chronic ankle instability.

2. Procedures

First, the displacement of the center of pressure during SitTS and StandTS was measured through BioRescue (RM Ingénierie, Marseille, France). In order to prevent compensation, the arms crossed in an X-shape and sit to stand to sit with the measurer's signal three times, and the average of the results was derived. In particular, when performed once, the operation execution time was unified in 3 seconds to sit to stand and 3 seconds to stand to sit.

Next, the limits of stability (LOS) and Y-balance tests were performed, measured three times each, and the average of the results was derived.

3. Outcome measures

1) Balance

The balance ability was measured through the LOS and the Y-balance test. LOS was measured using BioRescue. LOS is one of the biomechanical factors important for balance and measures the maximum range of the center of pressure displacement without losing its balance without changing the base of support (Kim & Choi, 2018). The measurement method is for the subject to voluntarily move from a standing posture, and to measure the pressure in four linear directions, left, right, front, and back, among the eight directions indicated by the monitor, and four oblique directions, left front, left back, right front, and right back. The center was moved to the maximum, and at this time, the trajectory drawn by the COP and the area were measured (Kim & Choi, 2018). It is an evaluation tool with high reliability (ICC=.84) (Kim & Choi, 2018).

The Y-balance test is a measurement method designed to increase repeatability of the star excursion balance test (SEBT), which is commonly used to measure muscle strength, flexibility, and proprioception in the lower extremities (Ko et al., 2019). The lines in the back inward and backward outward direction were marked at 135 ° on both sides based on the forward line using a 1.5 inch tape, and the distance from the center line to the point where the subject stretched legs was measured in cm, and then recorded after measuring it 3 times. If the supporting foot falls off the ground, supports the floor with the feet stretched out to balance, or fails to return to the starting position after stretching the foot, it is considered a failure and remeasurement (Ko et al., 2019). This test method evaluates the proprioception of the ankle by selecting three of the eight directions of the SEBT, front, medial back, and lateral back, and is an evaluation tool with very high reliability (ICC=.91) (Boey & Lee, 2020).

2) Center of pressure displacement

The center of pressure displacement was measured using BioRescue. It is an instrument used to evaluate the center

of pressure displacement during SitTS and StandTS operations and can measure the area (㎟), length (㎝), and average speed(㎝/s) of the body's center of pressure during a specific movement (Kim & Choi, 2018).

4. Statistical analysis

The general characteristics of the study subjects calculated the mean and standard deviation through descriptive statistics.

For normality test, Shapiro-Wilk test was performed and normality was confirmed. Independent t-test was performed to compare the center of pressure displacement and balance ability of the CAI group and the normal group during the SitTS and StandTS. Pearson correlation analysis was conducted to find out the correlation between the center of pressure displacement and the balance ability during the SitTS and StandTS.

The statistical significance level was set to .05, and SPSS (SPSS 22.0 for Window, IBM Corp., USA) was used for statistical analysis.

Ⅲ. Results

1. General characteristic of subjects

There was no statistically significant difference in the general characteristics of gender, age, and leg length of 63 subjects in the study, and there was a statistically significant difference in CAIT (Table 1).

Table 1. General characteristic of subjects (n= 63)

Variables (unit)	NG (n=33)	CG (n=30)	χ^2/t
Gender (man/woman)	18/15	17/13	.39
Age (years)	20.88±.58[a]	22.33±1.25	1.84
Leg length (㎝)	84.90±4.81	85.50±5.79	-.06
CAIT (scores)	25.50±1.50	17.40±2.50	-2.16*

*p<.05, [a]Mean±SD; mean±standard deviation, NG; normal group, CG; chronic ankle instability, CAIT; cumberland ankle instability tool

2. Comparison of the center of pressure displacement and balance ability

In the case of the COP displacement, there was a significant difference between the two groups of speed and length during SitTS and StandTS (p<.05).

In the case of balance, both LOS and Y-balance test showed significant differences between the two groups (p<.05) (Table 2).

Table 2. Comparison of the center of pressure displacement and balance in normal and chronic ankle instability group (n= 63)

			NG	CG	t
Center of pressure displacement	Sit to Stand	Speed (㎝/s)	4.66±1.10[a]	7.56±1.93	-7.37*
		Length (㎝)	18.33±6.38	32.08±8.17	-7.48*
	Stand to Sit	Speed (㎝/s)	4.29±1.44	6.85±2.02	-5.81*
		Length (㎝)	14.76±5.31	24.74±7.60	-6.08*
Balance	Limit of stability (㎟)		8943.06±6418.82	7209.67±3571.00	3.25*
	Y-balance test (㎝)		91.64±9.22	68.75±10.14	9.35*

*p<.05, [a]Mean±SD; mean±standard deviation, NG; normal group, CG; chronic ankle instability group

3. Correlation of the center of pressure displacement and balance ability

For speed of the COP displacement during SitTS, the length of the COP displacement during SitTS (r=.877, p<.01), the speed of the COP displacement during StandTS (r=.667, p<.01), the length of the COP displacement during StandTS (r=.679, p<.05), LOS (r=-.253, p<.05), Y-balance test (r=-.620, p<.01). For the length of the COP displacement at the time of SitTS, the speed of the COP displacement at the time of StandTS (r=.669, p<.01), the length of the COP displacement during StandTS (r=.684, p<.01), LOS (r=-.158, p<.05), Y-balance test (r=-.605, p<.01). In the case of the speed of the COP displacement during StandTS, the length of the COP displacement during StandTS (r=.782, p<.01), LOS (r=-.131, p>.05), Y-balance test (r=-.574, p<.01). For the length of the COP displacement during StandTS, LOS (r=-.190, p>.05), Y-balance test (r=-.559, p<.01). For LOS, Y-balance test (r=.201, p>05) (Table 3).

Table 3. Correlation of the center of pressure displacement and balance in normal and chronic ankle instability group (n= 63)

	SitTS_length	StandTS_speed	StandTS_length	LOS	YBT
SitTS_speed	.877**	.667**	.679*	-.253*	-.620**
SitTS_length	1	.669**	.684**	-.158*	-.605**
StandTS_speed		1	.782**	-.131	-.574**
StandTS_length			1	-.190	-.559**
LOS				1	.201
YBT					1

*p<.05, **p<.01, SitTS; sit to stand, StandTS; stand to sit, LOS; limit of stability, YBT; Y-balance test

Ⅳ. Discussion

Ankles are essential for activities of daily living and are associated with the ability to control balance, the ability to keep the body in equilibrium (Ha et al., 2018). CAI causes damage such as joint relaxation and deformation, degenerative changes in cartilage due to excessive ankle mobility, decreased neuromuscular control and control of lower extremity muscles, weakened muscle strength, and decreased joint range of motion (Jaber et al., 2018). In particular, when nerve tissues including mechanical receptors around the ankle are damaged, the ability to postural control decreases due to decreased proprioception associated with joint movement or position (Xue et al., 2021). Therefore, this study measured the balance between CAI subjects and normal people and the center of pressure displacement during SitTS and StandTS.

There was a significant difference in the balance ability between normal adults and CAI subjects and the COP displacement during SitTS and StandTS. Previous studies have reported that ankle sprains are highly associated with a decrease in posture control ability due to a decrease in sensory motor function (Hiller et al., 2011). The cause of the CAI subject's decreased ability to postural control is that damage to sensory receptor located on the lateral part of the ankle leads to loss of afferent information, which is a limitation of smooth sensory input (McKeon et al., 2015). In particular, it limits the ability to quickly generate new movement patterns to control posture and return to stable posture after external perturbation is applied, and this

deterioration in the ability of the self improvement system increases muscle relaxation time and reduces neuromuscular stability (Radovanovic et al., 2015). It has been reported that the difference in anteroposterior stability index and mediolateral stability index between normal subjects and the CAI group suggests that it is caused by neuromuscular control disorder (Youssef et al., 2018). As a result, it is considered that the balance ability and postural control ability of CAI subjects decreased compared to normal people.

COP displacement during SitTS showed a significant correlation with COP displacement during StandTS, LOS, and Y-balance test. The COP displacement during StandTS showed a significant correlation with the Y-balance test. In particular, displacement of COP and Y-balance test showed a high correlation compared to LOS. It is thought that the reason why the Y-balance test has a relatively high correlation is that it is a test that uses more joints of the lower extremities compared to the LOS. A previous study that performed kinematic analyzes of CAI subjects on postural control found that anteroposterior postural stability was maintained by using lower extremity movement patterns beyond normal movements to compensate for stability due to reduced ankle use strategies due to instability (Doherty et al., 2014). In addition, muscle weakness and limited range of motion in the ankle joint indicate compensation in the knee joint, hip joint, and trunk to achieve balance, and loss of ankle joint control ability indicates mechanical limitations in balance ability (De La Motte et al., 2015). As a result, smooth control of the hip joint, knee joint, and ankle joint is required to perform the SitTS and StandTS and the Y-balance test, so it is considered to show a significant correlation. Measurement of SitTS and StandTS COP displacement during the evaluation of CAI posture control suggests that this is meaningful.

This study has several limitations. First, there is a limit to the generalization of research results because the number of subjects is somewhat insufficient and the age is limited to those in their 20s. Second, there was no movement analysis of the knee joint and hip joint. Therefore, in future studies, it is necessary to recruit more subjects with ankle instability, consider various age groups, and conduct extensive research through various approaches to motion analysis.

Ⅴ. Conclusion

This study was conducted to compare postural control ability and balance ability through sit to stand to sit movements of subjects with CAI and normal people. CAI shows that there is a lot of sway in the body due to compensation to replace the decrease in ankle joint ROM when performing SitTS and StandTS due to sensory input damage such as decrease in ankle ROM and decrease in ankle proprioception. From this, CAI is expected to have a negative effect on our daily lives by influencing essential movements in life. The results of this study will serve as the basis for the dynamic approach to objective evaluation, treatment, and prevention of CAI, and in particular, the measurement of center of pressure displacement at the time of SitTS and StandTS will contribute to increasing the understanding of the biomechanical mechanism and kinematic analysis of CAI movements, and consequently, will have a positive effect on the improvement of CAI.

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