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Original Article

# Effects of Floss Bands on Ankle Joint Range of Motion and Balance Ability

Byoung-Hyoun Moon[1], PT, MS, Ji-Won Kim[2], PT, PhD

[1]Department of Physical Therapy, The Graduate School, Nambu University, [2]Department of Physical Therapy, Nambu University, Gwangju, Korea

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Corresponding Author
Ji-Won Kim
E-mail: rehab@nambu.ac.kr
https://orcid.org/0000-0002-6362-2312

**Key Words**
Ankle joint
Dynamic balance
Floss band
Range of motion
Static balance

**Background:** The range of motion (ROM) and balance ability of the ankle joint affect the stability of the ankle and prevent injuries or hurts from falling. In the clinical tests conducted recently, the floss band is widely used to enhance the range of joint motion and exercise performance, and there are many studies that have applied it to ankle joint increasing dorsi flexion (DF) angle.

**Objects:** This study compared the effects on the range of ankle motion and static/dynamic balance ability of the ankle through three conditions (before floss band intervention, after floss band intervention, and after active exercise intervention) for adults.

**Methods:** One intervention between floss band and active exercise was applied randomly and another intervention was applied the next day. After each intervention, the ROM of the ankle joints and the static balance was checked by measuring conducting one leg test. And the dynamic balance was checked by conducting a Y-balance test.

**Results:** In the case of DF, the range of joint motion showed a significant increase after floss band intervention compared to before floss band intervention ($p < 0.05$). Static balance ability showed a significant increase after the intervention of floss band and active exercise compared to before the intervention of floss band ($p < 0.05$). The dynamic balance ability showed a significant increase after the intervention of the floss band compared to before intervention of the floss band and after active exercise intervention ($p < 0.05$).

**Conclusion:** Based on these results, it was confirmed that the application of floss band to the ankle joint increases DF and improves the static and dynamic balance ability. Based on this fact, we propose the application of a floss band as an intervention method to improve the ROM of the ankle joint and improve the stability of the ankle in clinical field.

## INTRODUCTION

Since the ankle joint is used a lot in everyday life, many injuries occur accordingly, and the prevalence rate of damage reaches up to 55.3% [1]. The number of people with ankle joint injuries is increasing every year due to the increase in the number of occupations that walk or stand for a long time, and is expected to triple by 2030 [2]. Generally, ankle joint injury is thought to be mild, but 70% of people with ankle joint injury will have a physical disability [3]. When damage to the ankle joint occurs, this situation restricts long-term physical activity and reduces the quality of life [4].

The ankle joint is essential for daily life and balance, and plays an important role in the interaction between the lower extremity and the support surface in terms of kinematics [5]. The ankle joint provides feedback through the somatosensory system to maintain balance. In addition, the ankle joint uses information transmitted from the relationship between the body and the surrounding environment, the muscle spindle, golgi tendon organ, joint receptors, and skin receptors in the feedforward mechanism, and has the ability to regulate balance ability through ankle strategies [6,7]. However, when the ankle joint is injured, the range of motion (ROM) and stability of the ankle joint deteriorates, which causes problems with balance ability [8,9].

In order to prevent the damage of the ankle joint and enhance the balance ability, there are various interventions applied in clinical field. In clinical field, ankle joint mobilization and therapeutic exercise are often applied, and patients are encouraged to apply taping or orthosis that can control unstable movements [10,11]. When taping is applied to the ankle joint, the stability of the ankle improve the stability of the ankle, and support the damaged muscle to prevent further damage [12]. However, when applying taping, contact dermatitis, blisters, or allergic reactions may occur due to the adhesive [13]. In addition, prolonged use of orthosis may cause muscle weakness due to limited ROM [14]. Recently, floss band are often applied at rehabilitation filed as a conservative method to prevent from ankle joint damage.

Floss band began to gain popularity in 2013 when a book published by Starrett and Cordoza [15] became a New York Times bestseller. The floss band is made of natural rubber and is harmless to the human body. Not only that, it is known to be effective in relieving pain, increasing joint ROM, strengthening muscle strength, and improving coordination, to the extent that it is called voodoo (meaning inexplicable magic) [16,17].

Many studies on floss band have been conducted by many researchers. Driller and Overmayer [18] reported that the ROM of the ankle joint and jumping ability are improved when the floss band is applied to the ankle. In particular, when dorsi flexion (DF) is increased, it is argued that it can be provided to prevent injuries to the knee because it reduces the load on the anterior (ANT) cruciate ligament [18]. A study was conducted in which 30 subjects confirmed changes in the ROM of the knee joint by applying floss band, foam rollers, and joint mobilization to the knee joint. Through this, it has been proven that floss band is effective in ROM improvement compared to foam rollers and joint mobilization [19]. Kiefer et al. [20] on the other hand, confirmed the flexibility of 60 members of the general public according to the presence or absence of floss band in the shoulder joint, and as a result, showed no significant differences between the groups.

There has been a study that examined changes in ROM and exercise performance by applying floss band to various joints. However, the reality is that there is a lack of research on the ROM of the ankle joint and static and dynamic balance ability by the application of floss band. Therefore, the purpose of this study is to analyze the changes in ROM and static and dynamic balance ability of the ankle joint under three conditions (before floss band intervention, after floss band intervention, and after active exercise intervention).

# MATERIALS AND METHODS

## 1. Sample Size and Subjects

It was calculated using the G-power 3.1.9.2 program (Franz Faul, Kiel University, Kiel, Germany) according to Cohen's sample calculation formula to calculate the required number of research subjects according to the purpose of the study. G-Power analysis has set the statistical test as one way-repeated ANOVA, the effect size was set to 0.4, the large size of the F-test, and the significance level was set to 0.05 and power to 0.95, and then the sample size was calculated. The minimum sample size is 18. Considering the dropout rate of the study subjects, 25 people, which is 20%, were collected. This study was conducted on 25 healthy adults. To be eligible for the study, all participants were required to be free from lower extremity injuries that may have affected their ability to perform the one leg stand [18].

## 2. Research Procedure

This study compared ROM of ankle joint, static balance ability, and dynamic balance ability when applying three conditions (before floss band intervention, after floss band intervention, and after active exercise intervention). Before applying the floss band, measurements (ROM of the ankle joint, static balance ability, and dynamic balance ability) were performed first. After that, a floss band or active exercise was applied through a random method, and then the measurement was carried out again. Next day, we conducted the measurement after performing the rest of the intervention. The purpose of this study is to determine the effects of floss band on the ROM of the ankle joint and balance. The active exercise included in the intervention method includes active exercise in the floss band application method. Therefore, it was included as an intervention to check whether active exercise affects the experimental results. The design of this study is as follows (Figure 1). This study was reviewed and approved by the Nambu University's Institutional Bioethics Committee (IRB no. 1041478-2022-HR-008). The study process was explained to all the subjects prior to the study, and all subjects signed an informed consent form.

## 3. Intervention and Measurement

### 1) Floss band intervention

In this study, to apply the pressure to the ankle joint, the

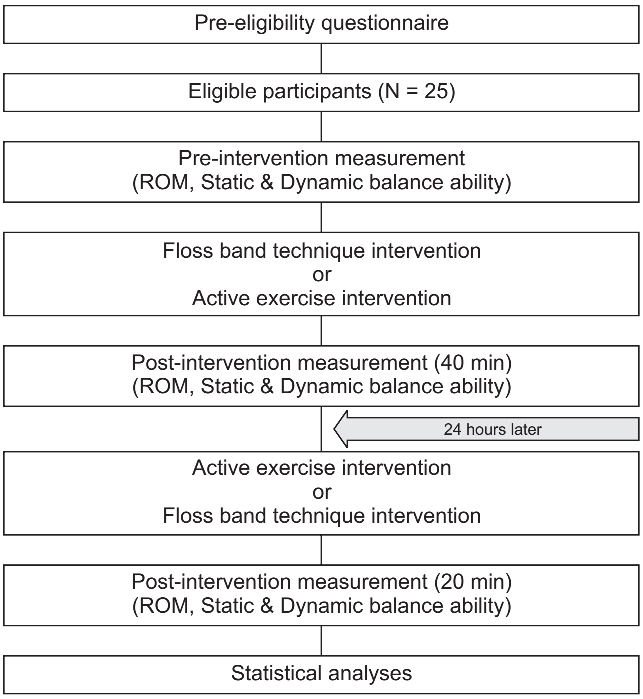


Figure 1. Flow chart of this study. ROM, range of motion.

floss band (Sanctband COMPRE Floss, LIME GREEN; PENTEL SDN.BHD., Shah Alam, Malaysia) was applied. The thickness of the floss band is 1.1 mm, the width is 5 cm, and the length is 2 m. To apply the floss band, it start at the dorsal of fifth metatarsal bone and wrap it horizontally twice through the metatarsal bone. After that, it comes to the medial malleolus, passes through the achilles, goes to the lateral malleolus, and then winds back to the medial malleolus by applying the figure eight knot method and winding it 3 times in total. Then, after passing achilles from the medial malleolus, the end knot was formed by wrapping it twice with the lateral malleolus on the edge side. The floss band were wrapped so that they overlapped by 50% to the extent possible to limit blood flow. Subjects were instructed to slow down active exercise (DF and plantar flexion [PF]) at low intensity for 2 minutes after applying the floss band. After that, the floss band was removed, and in order to normalize blood flow again, they walked lightly on a flat ground for about 1 minute, and the blood flow recovered (reperfusion) (Figure 2) [18].

### 2) Active-exercise intervention method

In the active exercise, subjects were instructed to the DF and PF of the ankle with slowly full range of active exercise of low-intensity for 2 minutes without applying floss band in the open kinetic chain state of sitting position. After 2 minutes, the subject was asked to walk lightly on the flat ground for 1 minute in the same way.

Figure 2. Floss bands intervention.

### 3) Test for ROM

A goniometer was used to measure the manual joint motion range of the ankle, and the operating range of DF and PF was measured. The axis was measured with the lateral malleolus, the stationary arm at the fibular head, and the moving arm parallel to the fifth metatarsal bone in the neutral state of the ankle [21]. The intra-rater reliability of the passive joint ROM measurement of DF and PF was Intraclass correlation coefficient (ICC) = 0.92–0.96 [22,23].

### 4) Static balance test

To measure the static balance ability of the ankle, one leg test (OLT) was measured using a wireless APDM Movement Monitoring inertial sensor system (APDM Inc., Portland, OR, USA). OLT was performed for 30 seconds to measure the sway area, and decreases sway area mean improving static balance. Three synchronized Opal inertial sensors were equipped on both ankles and lumbar L5 via straps. The signal is sampled, automatically processed, calculated, and streamed to a laptop via the corresponding "Mobility Lab™" software package (Mobility Lab™, Arlington, VA, USA). The OLT was conducted for 30 seconds, and when the starting sound was heard, the target person was instructed to stand with one foot and balance. If the foot touched the ground 30 seconds before, it was considered a failure and carried out again. The inter-rater reliability of APDM is ICC = 0.905–0.991 [24,25].

### 5) Dynamic balance test

The Y-balance test Lower Quarter (YBT-LQ; Move2Perform, Evansville, IN, USA) was used to measure the dynamic balance of the ankle. YBT-LQ consists of three pipes and one plate, and there is an indicator for measurement on each pipe. YBT-LQ has pipes in three directions from the support to the ANT, posterior-lateral (PL) direction, and posterior-medial (PM) direction, and the angle between the front and back pipes is 135°, and the pipe angle between the back inner and back sides is 90°. Every pipe is marked with distances in 0.5 cm. The subject's measurement foot is started in a single leg stance state by attaching the big toe to the red line of the plate. With the unsupported foot, the indicator in each direction should be reached to the tip of the toe to the maximum and returned again. At this time, if the foot touches the ground after losing the center, or kicking the indicator, the inspection method was explained again and re-measured. The value for measurement is the distance of the pipe on which the indicators are placed, and the study used the average value by 3 times each and normalized it [26].

Composite score (CS) = ([ANT reach distance + PM reach distance + PL reach distance]/3 × leg length) × 100 [27].

YBT-LQ showed inter-rater reliability (r = 0.85–0.91) and intra-rater reliability (r = 0.85–0.93) [28].

## 4. Analysis Method

In this study, were calculated using IBM SPSS ver. 22.0 Statistics software (IBM Co., Armonk, NY, USA) program was used for statistical analysis. The mean ± standard deviation was calculated by using technical statistics for the general characteristics of the subjects. All data were performed by Kolmogorov-Smirnov for normality tests. One way-repeated ANOVA was performed to compare three conditions of the ankle joint (before floss band intervention, after floss band intervention, and after active exercise intervention). The significance level for analysis was set at $P \leq 0.05$. The post hoc test was conducted through Bonferroni analysis, significance level was set at $P \leq 0.05/3$.

# RESULTS

## 1. General Characteristics of Research Subjects

A total of 25 people were studied, and their general characteristics were presented in Table 1.

## 2. ROM of Ankle Joints

The study measured DF and PF, and according to the results, there was a significant difference in DF among three conditions (before floss band intervention, after floss band intervention, and after active exercise intervention) ($p < 0.05$). There was no significant difference in PF ($p > 0.05$). According to the post hoc tests results, dorsiflexion ROM showed a significant increase after floss band intervention compared with before floss band intervention ($p < 0.05$) (Table 2, Figure 3).

Table 1. General characteristics of subjects (N = 25)

| Variable | Subject |
|---|---|
| Age (y) | 29.4 ± 3.6 |
| Height (cm) | 168.4 ± 8.2 |
| Weight (kg) | 67.4 ± 17.3 |
| Body mass index (kg/m$^2$) | 23.4 ± 4.2 |

Values are presented as mean ± standard deviation.

Table 2. Comparison of ROM and balance ability among three conditions (N = 25)

| | Pre-intervention | Floss band | Active exercise | F | p-value | post hoc |
|---|---|---|---|---|---|---|
| DF (°) | 9.0 ± 4.14 | 13.36 ± 3.96 | 10.52 ± 3.48 | 39.785 | 0.000* | A |
| PF (°) | 48.8 ± 10.37 | 49.72 ± 10.12 | 49.2 ± 9.85 | 1.017 | 0.377 | |
| OLT (mm$^2$) | 28.52 ± 14.0 | 13.24 ± 6.16 | 17.86 ± 8.03 | 36.843 | 0.000* | D,E |
| ANT | 61.12 ± 6.39 | 67.0 ± 5.98 | 61.78 ± 4.71 | 35.022 | 0.000* | A,C |
| PL | 108.0 ± 9.60 | 117.36 ± 9.27 | 110.71 ± 7.16 | 13.426 | 0.000* | A |
| PM | 105.49 ± 9.52 | 113.36 ± 7.35 | 108.45 ± 8.44 | 29.244 | 0.000* | A |
| CS | 91.54 ± 6.61 | 99.24 ± 6.11 | 93.65 ± 5.35 | 46.323 | 0.000* | A,C |

Values are presented as mean ± standard deviation. Significant difference by Bonferroni adjustment ($p < 0.05/3$). A: Pre-intervention < Floss band, B: Pre-intervention < Active exercise, C: Active exercise < Floss band, D: Floss band < Pre-intervention, E: Active exercise < Pre-intervention. ROM, range of motion; DF, dorsi flexion; PF, plantar flexion; OLT, one leg test; ANT, anterior; PL, posterior-lateral; PM, posterior-medial; CS, composite score. *$p < 0.05$.

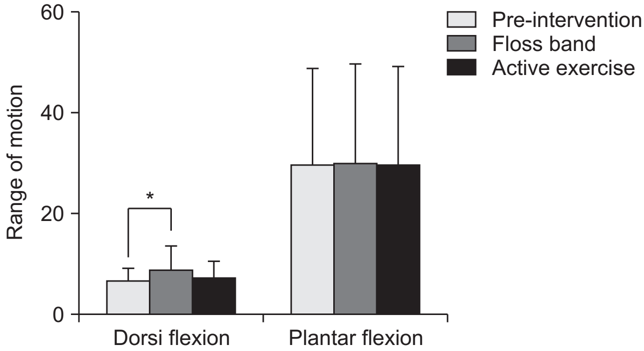


Figure 3. Effects of among three conditions on ankle range of motion. *p < 0.05.

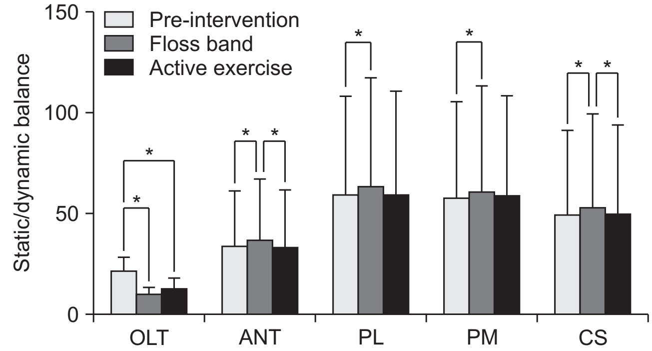


Figure 4. Effects of among three conditions on ankle static and dynamic balance ability. OLT, one leg test; ANT, anterior; PL, posterior-lateral; PM, posterior-medial; CS, composite score. *p < 0.05.

### 3. Static Balance Ability

OLT showed significant differences among three conditions (before floss band intervention, after floss band intervention, and after active exercise intervention) ($p < 0.05$). Post hoc tests results showed significant decreases after floss band intervention and after active exercise intervention compared with before floss band intervention, respectively ($p < 0.05$) (Table 2, Figure 4).

### 4. Dynamic Balance Ability

There were significant differences in ANT, PL, PM, and CS among three conditions (before floss band intervention, after floss band intervention, and after active exercise intervention) ($p < 0.05$). According to the results of the Post hoc tests, ANT showed a significant increase after the floss band intervention compared with before the floss band intervention and after the active exercise intervention ($p < 0.05$). PL showed a significant increase after floss band intervention compared to before floss band intervention ($p < 0.05$). PM showed a significant increase after the floss band intervention compared to before the floss band intervention ($p < 0.05$). YBT-LQ CS showed a significant increase after floss band intervention compared to before floss band intervention and after active exercise intervention ($p < 0.05$) (Table 2, Figure 4).

## DISCUSSION

Recently, floss band have been widely used as an intervention method to improve the ROM and exercise performance of the ankle joint. However, there are not sufficient research on the ROM of ankle joint and balance ability by applying floss band to the ankle joint.

Therefore, the purpose of this study examines the effects of floss band intervention on the ROM of the ankle joint and static and dynamic balance ability. According to the results of this study, there was a significant increase in the ROM of DF after floss band intervention compared to before floss band intervention. This is a result that corresponds with the result from prior research [18,29]. The ROM of increased DF is considered to be due to increased flexibility of the muscles around the ankle joint due to muscle compression by the floss band. The mechanism for increasing flexibility is that when mechanical pressure is applied to the muscle, heat is generated that reduces the viscoelasticity of the muscle, and the various fibrous layers of the myofascial and the collagen connective tissue are separated to elongate the muscle, and the floss band used this principle [30]. In addition, as the blood flow increases and hyaluronic acid, which improves the movement of the myofascial, normalizes, the ROM of the joint appears to be increased [31].

In this study, static balance ability was measured through OLT of sway area. According to the results, the static balance ability was significantly decreases after the intervention of floss band and after the intervention of the active exercise, respectively, compared with before the intervention of the floss band. According to prior studies, active exercise of the ankle can improve its balance ability by improving intrinsic receptivity through the mechanism such as neural learning and neuroplasticity [32,33]. Therefore, in this study, it is considered that the active exercise of the ankle included in the floss band intervention method enhances proprioception and the resistance to DF and PF by the floss band increases the exercise intensity. In addition, the improvement of static balance ability after floss band intervention is thought to be relevant with the increase in the ROM of the joint with DF. Various studies have reported that as the joint ROM of DF increases, the coordination and postural control abilities improve, and the static balance also increases [34,35].

Through YBT-LQ in this study, the dynamic balance ability was confirmed. YBT-LQ is a simple yet highly reliable evaluation method used to predict the risk of lower extremities injury and to determine return after sports injury [36,37]. In the results of this study, it was found that the normalized score after floss band intervention increased significantly in the ANT direction compared to before floss band intervention and after active exercise intervention. According to Nakagawa and Petersen [38] study, ANT in YBT-LQ showed that DF is a kinematics predictor, and that the ANT score can only increase if DF increases. For movement in the ANT direction, as the non-supporting leg moves forward, a sufficient range of DF joint motion must be secured for the supporting foot to ensure stability as the heel touches the ground so that balance can be maintained. Therefore, it is thought that applying the floss band increased the range of joint movement of DF, and the ANT normalized score was improved.

In the backward direction (PL and PM) of YBT-LQ, the normalized score after floss band intervention increased significantly compared to before floss band intervention. In order to perform PL and PM, sufficient ROM and muscle stability on the coronal plane of the supporting leg must be accompanied. Nelson et al. [39] research shows that increased rotation, including ankle abduction and adduction, improves the normalized score of PM. Although in this study, the ROM for the subtalar joint was not measured. However, floss band intervention would have affected the operating range of the coronal plane, and the normalized score in the backward direction would have increased.

YBT-LQ's CS showed a significant increase after floss band intervention compared to before floss band intervention and after active exercise intervention. Various studies have been conducted to identify the correlation between the risk of injury of athletes and CS. Butler et al. [40] investigated the correlation between CS and the risk of lower extremities injury among American football players. As a result, it was reported that the probability of non-contact lower extremities increased 3.5 times when CS was 89.6% or less. Plisky et al. [41] studied the relationship between star excursion balance test and risk of lower extremity injury in basketball players, and reported that in female players, when the CS was less than 94%, the risk of lower extremity injury increased by 6.5 times. In this study, the CS before floss band intervention increased from 91.54% to 99.24% after floss band intervention. Therefore, it shows that the training that includes floss band intervention is highly likely reduced the risk of lower extremities.

The limitation of this study is as follows. First, studies that confirmed the immediate effects of floss band but did not identify the effects over time. Second, this study experimented for the general public as the subjects, so it is difficult to generalize the result from this study to patients. In the future, research on subjects with ankle instability or ankle joint dysfunction will be needed.

## CONCLUSIONS

This study was conducted to investigate the effects of floss band on ROM and static and dynamic balance ability when applying floss band to the ankle joints in 25 healthy adults. Through the results obtained from this study, it was found that floss band increase the ROM, static and dynamic balance of joint for DF. Based on these results, it is seemed that applying floss band in clinical practice can help improve ROM, static, and dynamic balance of the ankle joint. In addition, the training which includes the floss band intervention for athletes may reduce the risks of injuries on the lower extremity.

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## CONFLICTS OF INTEREST

No potential conflicts of interest relevant to this article was reported.

## AUTHOR CONTRIBUTION

Conceptualization: BHM, JWK. Data curation: BHM, JWK.

Formal analysis: BHM, JWK. Funding acquisition: BHM, JWK. Investigation: BHM, JWK. Methodology: BHM, JWK. Project administration: BHM, JWK. Resources: BHM, JWK. Software: BHM, JWK. Supervision: BHM, JWK. Validation: BHM, JWK. Visualization: BHM, JWK. Writing - original draft: BHM, JWK. Writing - review & editing: BHM, JWK.

## ORCID

Byoung-Hyoun Moon, https://orcid.org/0000-0002-2146-5814

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