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Original Research

The effect of center-based versus home-based training for rehabilitation of chronic ankle instability in recreational athletes

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Abstract

Background: Ankle sprains are common in athletes and often progress to chronic ankle instability. Many individuals choose home-based (HB) training due to insufficient time, personal preferences, and accessibility. Therefore, the purpose of this study was to assess the effect of HB rehabilitation training. **Methods**: Forty adults (center-based (CB) group, n = 20; home-based (HB) group, n = 20) with chronic ankle instability were trained for 6 weeks and their data analyzed. For ankle strength training, tube bands or body weight, and dynamic balance exercises were used. The CB group trained 5 days/week at a center under physiotherapist monitoring; the HB group performed a self-monitored exercise program 4 days/week using their mobile device and a video-session program 1 day/week. Training intervention lasted 6 weeks; tests were conducted during weeks 1, 3, and 6. Ankle muscle strength was measured at an angular velocity of 30°/s and 120°/s using isokinetic equipment, and balance using the Y-balance test (YBT) including three direction; anterior, posteromedial, posterolateral. Hop tests—single, triple, crossover, and 6 m tests—were performed to evaluate lower extremity function, and subjective ankle evaluation using the foot and ankle outcome score (FAOS). **Results**: Ankle strength significantly improved with no between-group differences at 30°/s; at 120°/s, the CB group significantly improved compared to the HB group. The YBT and FAOS significantly improved in both groups at 6 weeks, with between-group differences. The hop test significantly improved in both groups. Single and triple hop test between-group differences were not significant; however, the CB group significantly improved in the crossover and 6 m tests compared to the HB group. **Conclusions**: The 6-week CB and HB rehabilitation programs improved muscle strength, balance, lower extremity function, and subjective ankle satisfaction in both groups. CB training showed a partially superior effect, although HB training recommended for participants who have difficulty visiting rehabilitation centers and may be an appropriate alternative.

Keywords: Home-based training; Rehabilitation; Center-based training; Strength; Balance; Chronic ankle instability

1. Introduction

Lateral ankle sprains caused by ankle inversion are high frequency and recurrence rate sports injuries sustained by athletes [1]. Athletes with ankle sprains exhibit a recurrence rate of 73.5%, with a 22% incidence of sprains repeated 4–5 times [2]. Therefore, although the initial ankle sprain injury is acute, it tends to progress and with repeated injuries eventually leads to chronic ankle instability (CAI) [3]. The literature defined CAI as "an encompassing term used to classify a subject with both mechanical and functional instability of the ankle joint" [4]. It has been reported that up to 70% of ankle sprains progress to CAI, and 40% of those with ankle sprain develop CAI within 1 year after the first sprain [5].

Typically, conservative treatment should precede surgical treatment. Conservative treatment includes rest, medication, and rehabilitation, and sometimes involves immobilization [6]. In a study among youth athletes, the recurrence rate of ankle sprains after rehabilitation training decreased compared to the control group. The control group and the training group recurrence injury rates were 7.4% and 3.4%, respectively [7]. Further, 22 participants with ankle sprains were recruited and balance training and proprioceptive neuromuscular facilitation intervention were performed for 6 weeks. As a result, balance ability and pain improvement were higher in the balance training group [8]. Nevertheless, surgery is usually performed when conservative treatment does not provide a satisfactory result [9].

It has been reported that athletes with ankle sprains do not receive systematic medical management despite high recurrence and probability of progression to CAI. In a study by Hubbard-Turner [10], 64% of the 175 athletes with CAI did not receive treatment following an ankle sprain, and their ankle assessment scores were significantly reduced. In addition, even among the athletes who received treatment, 100 received management of their joint range of motion, but only 74 received strength training, and none received balance training.

There are several reasons for limited participation in rehabilitation, including lack of transport and time to visit a rehabilitation center, while cost may also be a major consideration [11]. Recently, the closure of training facilities due to coronavirus disease (COVID-19) has been a factor limiting participation in rehabilitation [3,12]. HB training is an appropriate method to overcome these limitations and obtain the effect of rehabilitation. Moreover, recently, the diversification of exercise-related videos, wearable equipment, and game-type exercise programs improved the quantity and quality of HB training [13,14]. During the prolonged COVID-19 situation, the trend of home-based (HB) training is expected to increase. Therefore, we sought to analyze effects of HB training using mobile monitoring and center- based (CB) training conducted under physiotherapist supervision in non-professional athletes.

2. Materials and methods

2.1 Participants

Adult males (21–35 years old) who visited the sports rehabilitation center with CAI were recruited through the bulletin board. The specialist made the diagnosis by comprehensively considering the radiological information, physical examination, and Identification of Functional Ankle Instability (IDFAI) [15,16]. Among the 65 participants with Grade I and II ankle sprains who were diagnosed with CAI by a specialist and did not require surgery, we excluded participants with bilateral injuries (n = 5) and a history of ankle surgery (n = 2). Participants who had too much pain and limited range of joint motion, those who could not stand on one leg for the balance test, or those who did not complete the test were also excluded (n = 14). An additional 4 participants who were transferred to another hospital during the experiment were excluded. Finally, a total of 40 males participated in the experiment and their data were included in the analysis (20 in the HB training group, 20 in the CB training group). Participants are non-professional athletes who play at least once a week; soccer (n = 11), badminton (n = 7), tennis (n = 4), basketball (n = 9), taekwondo (n = 5), judo (n = 1), Baseball (n = 3). The allocation of CB and HB was decided in consideration of the participant's situation.

Evaluation was performed using the isokinetic muscle strength test, balance test, hop tests, and foot and ankle outcome score (FAOS) questionnaire. The same test was performed at weeks 3 and 6 following the initial test. All participants provided informed consent. The study complied with the tenets of the Declaration of Helsinki and was approved by the Institutional Ethics Review Board of the Gangneung-Wonju National University (GWNUIRB 2021-13).

2.2 Isokinetic strength test

The ankle muscle strength test was performed using Computer Sports Medicine Inc. isokinetic equipment (CSMi HUMAC NORM, Stoughton, MA, USA). In particular, the muscle strength of the peroneus muscle related to the eversion motion was measured. In order to demonstrate maximum muscle strength, the participant's condition and any other injuries were verbally discussed before the test. The test method and posture were previously described [17]. Participants were in the supine position and were instructed to bend the hip joint and knee to 90°. The height of the foot was adjusted so that both the knee and the heel were horizontal, and the foot was fixed to the test adapter. The feet, knees, pelvis, and upper body were maintained in the correct posture, and the thighs, hip joints, pelvis, and torso were fixed with pads, straps, and belts, respectively. The participant held the handrail. The zero-neutral position was aligned with the zero degree of the machine and the center of the tibia and aligned with the second toe (Fig. 1).

Cycling and stretching were performed for 20 min to warm up. The test angles were set to 35° inversion and 25° eversion. The tests comprised concentric contractions measured at an angular velocity of 30°/s and 120°/s. Angular velocity means the angle of movement in 1 s, 30°/s is low speed and 120°/s is high speed. Angular velocity is controlled by a computer, with 30°/s corresponding to low speed and 120°/s to high speed. These angular velocities complied with the low and high speeds suggested in the test guideline [17]. After the maximum contraction of the inversion, an eversion contraction was performed to return to the initial position. In order to fully understand the test, all participants were provided with clear instructions and allowed to practice. Before the actual test, the participants performed several movements at low, medium, and high speeds to gain familiarity with the machine; subsequently, the real test was performed.

Because the ankle is a weight-bearing joint, ankle strength was analyzed in two ways: absolute strength (Nm) and relative strength. The relative value was calculated using the following formula:

Relative value (%) = (absolute value / body weight) × 100

2.3 Y-balance test

Balance was evaluated using the Y-balance test (YBT) equipment [18]. Before the test, the measurer checked whether the participants were able to stand on one leg. Sufficient rest was performed after the isokinetic muscle strength test to exclude interference between tests. The examiner explained and demonstrated the examination method in detail to the participants, who were allowed to practice several times to ensure proper understanding. Participants were instructed to stand on one foot on a platform at the center of the test instrument and hold their center. The participant was asked to push the anterior, posterolateral, and posteromedial measuring instruments as much as possible whilst standing on one leg. If the participant lost balance, the test method was explained again and the test was performed again (Fig. 2). The procedure was repeated three times and the mean value was recorded (cm). The sum of values obtained for the three directions was divided by the length of the lower extremity, measured using a measuring tape from the anterior superior iliac spine to the center of the medial malleolus. The score was calculated as follows:

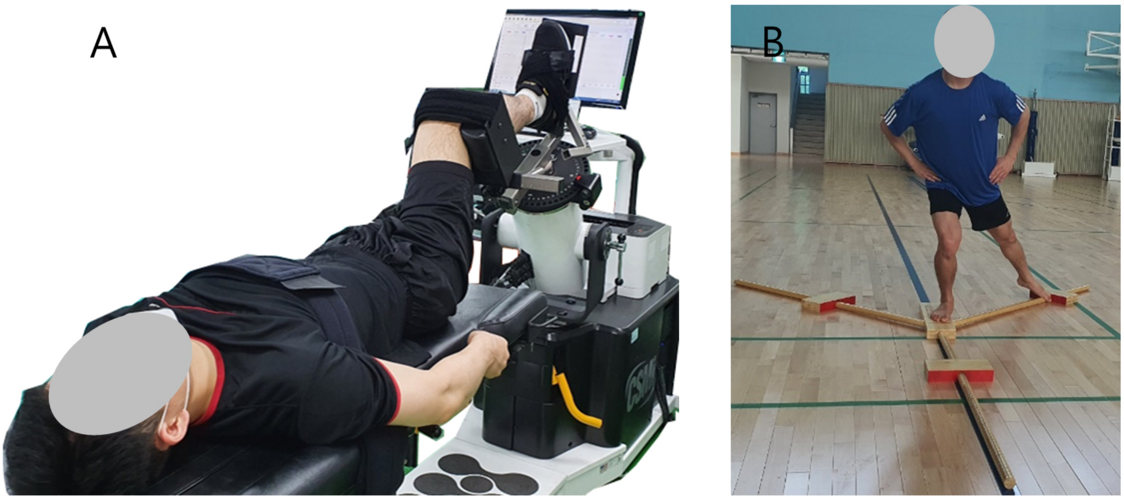

Fig. 1. Isokinetic strength test and Y-balance test. (A) Isokinetic strength test. (B) Y-balance test.

Score = [(sum of distance in 3 directions)/(length of lower extremity × 3)] × 100

2.4 Hop tests

The hop tests were performed to evaluate lower extremity function, and carried out in four ways: single, triple, crossover, and 6 m. The examiner confirmed the health of the ankles, knees, and waist on both sides to enable safe examination of the participant. The examiner first demonstrated the procedure, thereafter allowed the participant to practice, and subsequently tested the participant. The healthy leg was examined first, followed by the affected side. A total of four tests were performed [19]. In the single hop test for distance, the participant jumped as far as possible once. The triple hop test involved jumping on one leg, three times in a row. The crossover hop test required the participant to jump three times using one leg, alternating to the left and right of a center line. The 6 m hop test involved the participant jumping as quickly as possible over a distance of 6 m. The single, triple, and crossover hop tests involved the participant covering the longest possible distances (recorded in cm), whereas the 6 m hop test measured the time taken for completion (recorded in s). The tests were performed twice, and the highest value was used for analysis. If the participant lost their balance and the opposite leg touched the ground, a retest was performed.

2.5 Ankle questionnaire: foot and ankle outcome score

The FAOS questionnaire was used for subjective participant assessment of the ankle status. This questionnaire comprises 42 items as follows: symptoms: 7, pain: 9, daily functions: 17, sports and recreation functions: 5, and quality of life: 4 items. The score for each item is ranked from 0 to 4, with 0 being bad and 4 being good. A total score of 0 indicates a very poor condition, with extreme pain and poor quality of life. Conversely, a score of 100 indicates no symptoms, no pain, and no abnormalities [20].

2.6 Rehabilitation program

Rehabilitation training comprised strength training and proprioception training. In order to match the amount of exercise and shape of the CB training group and the HB training group as closely as possible, the quantity, method, time, number of sets, and frequency were described in detail. The exercise rehabilitation program was conducted 5 days/week for a period of 6 weeks. One session was designed to be performed for 30 min. The CB training group visited the center 5 days/week and trained under the supervision of a physiotherapist. The HB training group was provided with the program and performed training using their mobile device. The self-monitoring method was used on 4 days and exercise was performed once/week under real-time monitoring by a physiotherapist through a video conference program. In addition, the exercise log was recorded on a mobile device to confirm whether the exercise was continuously performed. The accuracy and method of movement were ascertained through mobile supervision, questions and answers, and consultation, and feedback was provided.

2.6.1 Ankle strength training

The strength training program involved a total of six elastic tube bands (TheraBand, Hygenic Corp., Akron, OH, USA). The band colors, yellow, red, green, blue, black, and gray, represent the order of increasing stiffness. After exercising for 1 week using one color, the next color was used. Elastic tube band training was performed in four directions: dorsiflexion, plantar flexion, inversion, and eversion, and the length, number of times, and number of sets were gradually increased to adjust the exercise intensity. For strength

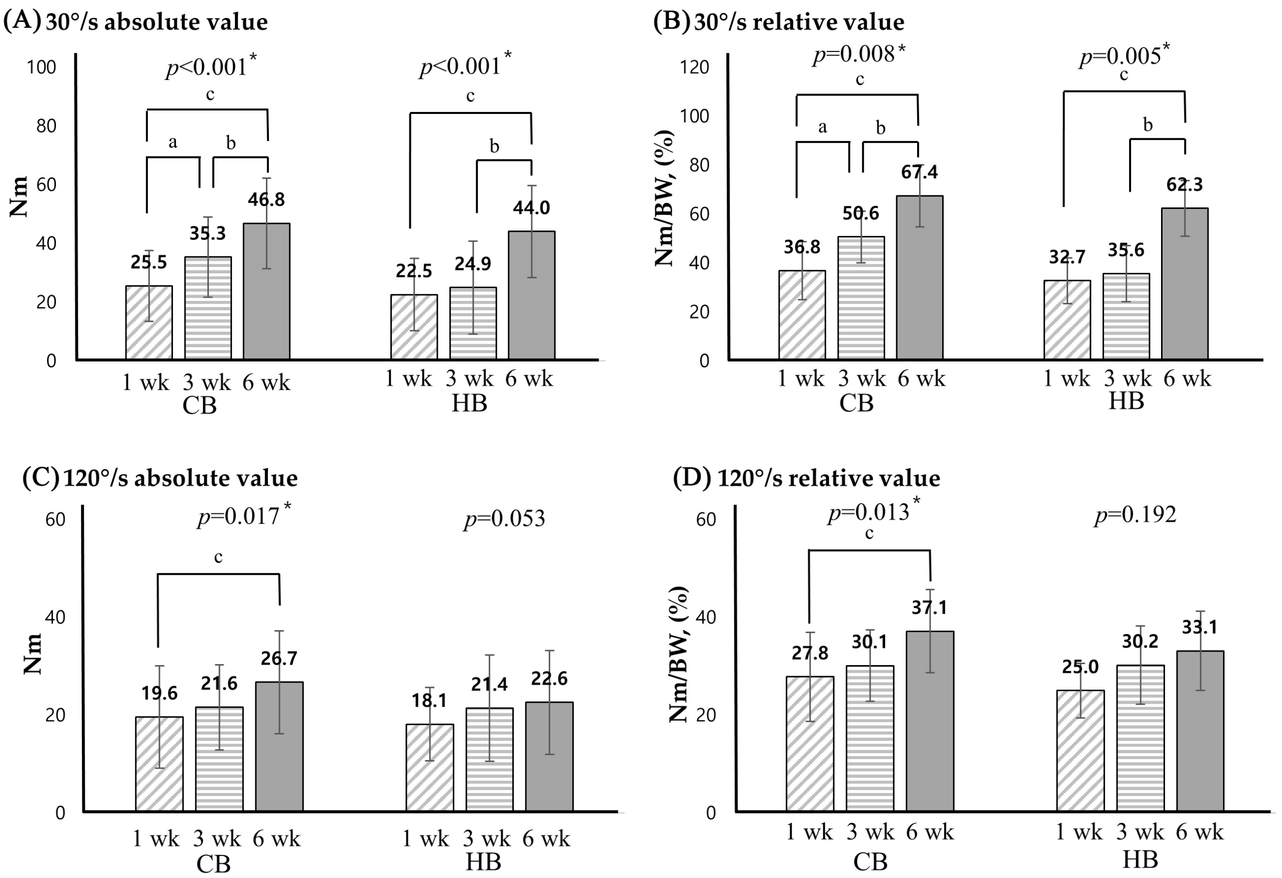

Fig. 2. Isokinetic eversion strength of CB training and HB training groups. *$p < 0.05$; a, b, and c mean the significance between measurement weeks (a, 1 week versus 3 weeks; b, 3 weeks versus 6 weeks; c, 1 week versus 6 weeks); CB, center-based; HB, home-based.

training using body weight, heel raise, toe raise, squat, and lunge exercises were performed. The amount of training was 20–30 repetition, 3–5 sets per day.

2.6.2 Balance training

For balance training, a stability trainer and gym ball (TheraBand, Hygenic Corp., Akron, OH, USA) and BOSU ball (NexGen, Ashland, OH, USA) were the tools used [21,22]. We also informed participants how to adjust the difficulty level to ensure safe exercise. The adjustment in difficulty was taught in order for participants to transition from both feet to one foot, a hard to soft surface, a short to long time, and performing simple to complex movements. The amount of training was determined by time and consisted of 3–5 sets of 5 min.

2.7 Statistical analysis

The following sample size conditions were set using G*power software (G*power 3.1, University of Düsseldorf, Düsseldorf, Germany): effect size, f = 0.25; α error = 0.05; power, (1-β err prob) = 0.95; groups, 2; and number of measurements, 3. The F-test and repeated measures, within-between interaction were used.

Data analyses were performed using SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Age, height, weight, and body mass index (BMI) are expressed as mean and standard deviation. The Shapiro–Wilk normality test was performed, and nonparametric Mann–Whitney U test was used for continuous variables, such as strength, YBT results, hop tests results, and the FAOS for comparison between groups. The Friedman test was performed for the 1st, 2nd, and 3rd comparison within the group, and the Wilcoxon post hoc test was performed. Categorical variables are expressed as percentage, and the chi-square test was performed. Statistical significance was set at $p < 0.05$.

3. Results

Age (p = 0.202), height (p = 0.858), weight (p = 0.550), and BMI (p = 0.648) were similar between the groups. There was also no difference between the groups on the injured side (p = 0.217) and the unaffected leg (p = 0.716). Most of the participants' recent injuries were within 2 weeks, 16 in the CB group and 17 in the HB group. And the frequency of ankle sprains within the last 3 months was 10 participants with 1–2 times and 7 participants with 3–4

Table 1. Participant characteristics in the CB and HB training groups.

	CB (n = 20)	HB (n = 20)	t or χ^2	*p*-value
Age, years	26.1 ± 4.0	26.7 ± 4.0	–1.299	0.202
Height, cm	174.7 ± 2.9	174.1 ± 4.8	0.180	0.858
Weight, kg	69.9 ± 5.6	70.4 ± 6.0	0.603	0.550
BMI, kg/m^2	22.9 ± 1.7	23.0 ± 2.0	0.460	0.648
Injury side, n (%)				
Right	11 (55.0%)	13 (65.0%)	0.718	0.217
Left	9 (45.0%)	8 (35.0%)		
Dominant side, n (%)				
Right	18 (90.0%)	17 (85.0%)	1.140	0.716
Left	2 (10.0%)	3 (15.0%)		
Last ankle sprain, n (%)				
<1 week	6 (30.0%)	7 (35.0%)		
1–2 weeks	10 (50.0%)	10 (50.0%)	1.486	0.686
3–4 weeks	4 (20.0%)	3 (15.0%)		
Frequency of ankle sprains for last 3 months, *n* (%)				
1–2 times	10 (50.0%)	12 (60.0%)		
3–4 times	7 (35.0%)	6 (30.0%)	0.459	0.795
> 5 times	3 (15.0%)	2 (10.0%)		

CB, center-based; HB, home-based.

times in the CB group, and 12 participants with 1–2 times and 7 patients with 3–4 participants in the HB group (Table 1).

3.1 Isokinetic strength test

The absolute and relative values of eversion at an angular velocity of 30°/s were significantly improved in both groups at 6 weeks. At an angular velocity of 120°/s, the CB training group had absolute (p = 0.017) and relative (p = 0.013) changes with time, but the HB group exhibited no change with time (Fig. 2).

3.2 Y-balance test

Balance was assessed using the YBT. Both groups showed significant improvement over time in all directions and overall scores. These results showed that both programs were effective (Fig. 3).

3.3 Hop test

Fig. 4 shows the results of hop tests evaluating one-leg jump ability. The hop test resulted in improved results at 6 weeks compared to the first week for all items in both groups. In the triple hop and crossover hop tests of the HB group, there was no significant difference between the 1 week and 3 weeks, but there was a significant improvement at the 6 weeks (Fig. 4).

3.4 Foot and ankle outcome score

Both groups exhibited a significant improvement in the FAOS at 3 weeks, and significantly improved at 6 weeks compared with the 1st and 3rd weeks ($p < 0.05$). These results revealed that both CB and HB training were effective in improving subjective satisfaction, and there was no significant difference (Table 2).

Table 2. FAOS score of the CB training and HB training groups.

Subject scoring	Time	CB	HB
FAOS	1 week	50.3 ± 28.3	55.6 ± 23.1
	3 weeks	65.4 ± 24.1 ^{a}	60.4 ± 21.5 ^{a}
	6 weeks	79.8 ± 10.9 ^{b,c}	83.1 ± 18.2 ^{b,c}
	p	<0.001*	<0.001*

*$p < 0.05$; a, b, and c mean the significance between measurement weeks (a, 1 week versus 3 weeks; b, 3 weeks versus 6 weeks; c, 1 week versus 6 weeks); CB, center-based; HB, home-based; FAOS, foot and ankle outcome score.

4. Discussion

One of the main results of this study was that muscle strength improved in both groups at low speed (30°/s), but at high speed (120°/s), CB training was more effective than HB training. In the 6 m hop tests, the CB training group showed more improvement than the HB training group. This result indicates that increased strength is exerted at high speed. These results are in agreement with those of previous studies [23,24]. A physiotherapist supervised training group and an HB training group were com-

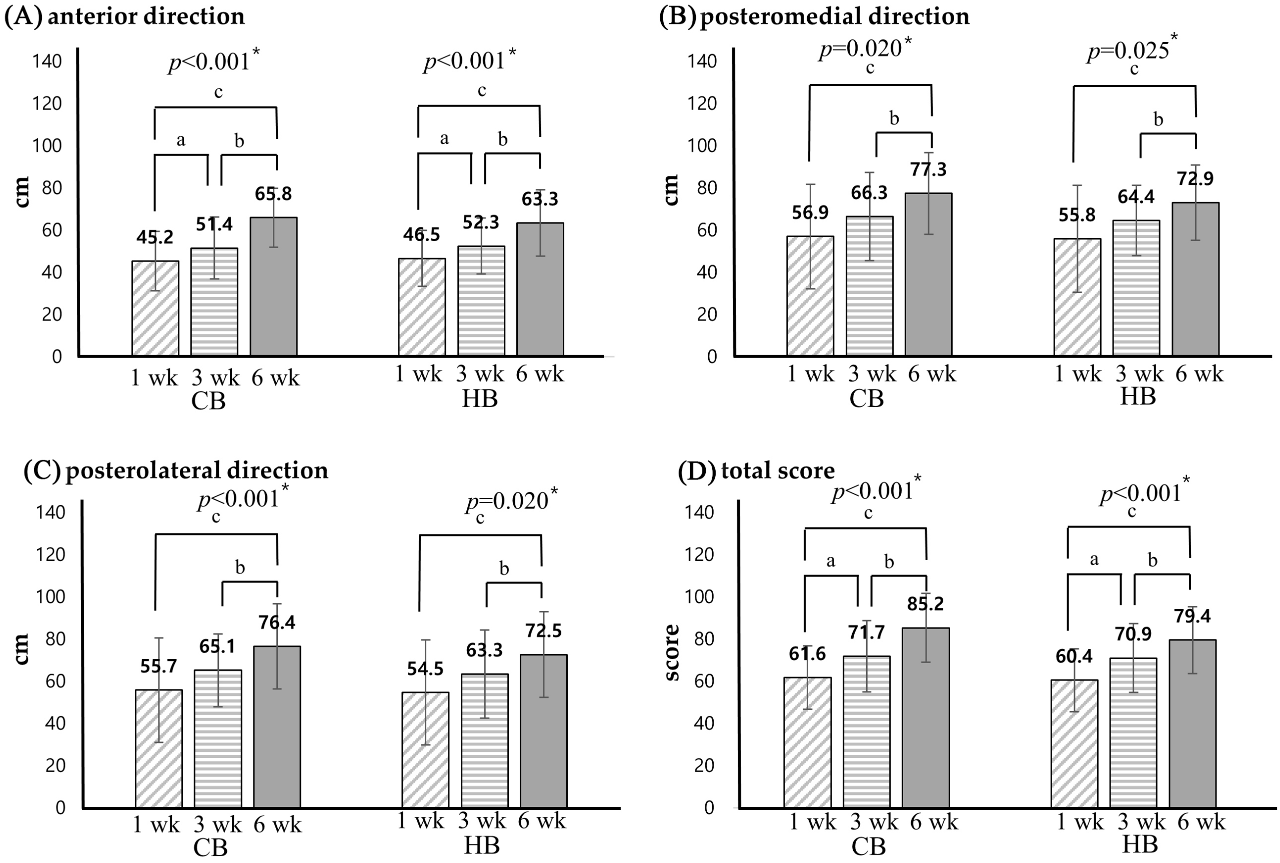

Fig. 3. Y-balance test of the CB training and HB training groups. *$p < 0.05$; a, b, and c mean the significance between measurement weeks (a, 1 week versus 3 weeks; b, 3 weeks versus 6 weeks; c, 1 week versus 6 weeks); CB, center-based; HB, home-based.

pared for participants with ankle sprains, and the data were analyzed after exercise intervention and follow-up for 6 months. For evaluation, the Foot and Ankle Ability Measure (FAAM), Lower Extremity Functional Scale (LEFS), numeric pain rating scale, and activities of daily living were measured. The results revealed that the physiotherapist supervised training group exhibited greater improvement in the FAAM and LEFS scores than the HB training group [23].

Meanwhile, there are studies that have reported that HB training is valuable [25–27]. In a study that recruited 522 participants and analyzed the recurrence of ankle injury, the intervention group performed proprioception training with HB training, and the control group was restricted proprioception training. Exercise intervention was conducted for 8 weeks and the occurrence of ankle sprains was investigated for 1 year. The results indicated that ankle sprains recurred in 145 participants: 56 (22%) in the HB training group and 89 (33%) in the control group. Therefore, the HB training intervention group reported a 35% reduction in the risk of recurrence compared to the control group [27]. In another study, when HB training and clinic-based training were compared, training attendance was found to be 87% for the clinic group and 96% for the home group. A comparison of the Sport Injury Rehabilitation Adherence Scale between groups revealed no significant difference [25]. In addition, when pre–post comparisons were made after 8 weeks of balance training among 33 CAI participants following an HB training program, the Foot and Ankle Disability Index and Visual Analogue Scale scores significantly improved [26]. Therefore, both CB and HB training are effective rehabilitation methods for participants with CAI or ankle sprain. However, while it cannot be argued that HB training is superior to CB training, it can be said that HB training is very effective.

Advantages of HB training include accessibility, no time limitation, privacy protection. On the other hand, disadvantages include low motivation, lack of exercise space, and difficulty controlling or monitoring under the therapist [28]. Our results also showed that, in part, the CB training performed better improvement, which was probably more influenced by the advantages of the CB training group. In previous study, a meta-analysis reported that CB training was more effective than HB training on pain, subjective instability, and ankle strength and joint position sensation in ankle sprain [24]. Using a remote rehabilitation method with mobile supervision is an effective way to compensate for the shortcomings of HB training. In particular, a system

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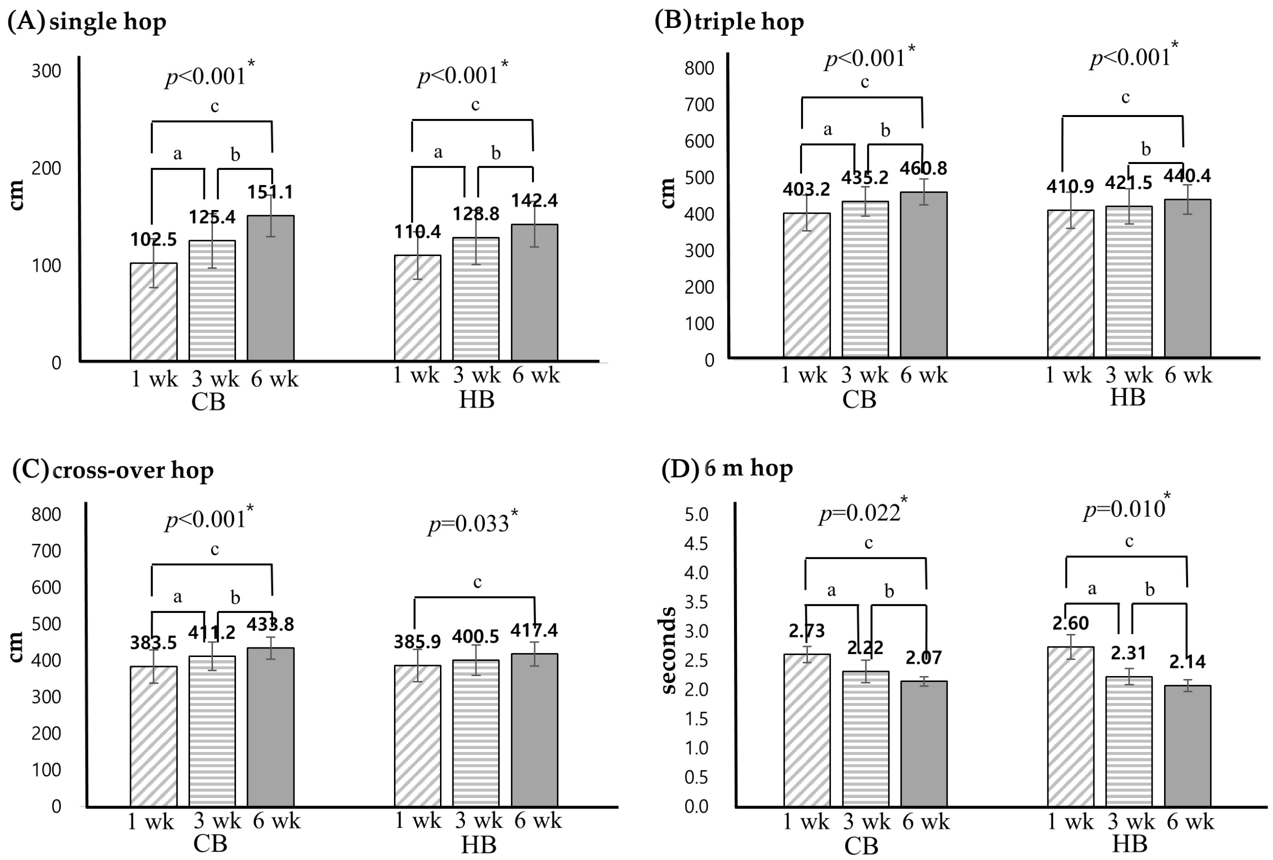

Fig. 4. Hop tests of the CB training and HB training groups. *$p < 0.05$; a, b, and c mean the significance between measurement weeks (a, 1 week versus 3 weeks; b, 3 weeks versus 6 weeks; c, 1 week versus 6 weeks); CB, center-based; HB, home-based.

developed using a game or robot has the characteristics of generating interest, visualizing information, enhancing the development of wearables, and receiving immediate feedback [13,29]. As a result of applying the game-type exercise system to participants with ankle sprains for 6 weeks, the intervention group showed significant improvement in the ankle function score and pain during walking compared to the control group [30].

As a result of our study, the YBT, was found to be effective in both groups. Several studies suggest that balance training is effective in preventing recurrence of ankle sprains and CAI [8,27]. Hupperets *et al*. [27] reported a low recurrence rate in the balance training group. In a study of neuromuscular training for youth soccer players, a control group (n = 364) and training group (n = 380) were followed. Knee sprain occurred in 8 participants in the control group and 3 in the training group, whereas ankle sprain occurred in 27 and 14 participants in the control and training groups, respectively [7].

In our present study, strength and balance training were combined, but the effects of the two exercises have rarely been compared. Forty participants with CAI were divided into a wobble board group and a tubing strength training group and trained for 4 weeks. Subjective satisfaction was evaluated using the Star Excursion Balance Test, figure-of-8 hop test, side-hop test, and four questionnaires. Comparison of the two groups revealed that wobble board training was more effective than strength training [31].

Treatment of CAI includes taping and braces in addition to the strength and proprioception training used in this study; however, their effectiveness remains controversial [32,33]. Our study has the following strengths. Among the studies comparing HB training and CB training, there are not many targeting CAI participants, and most used questionnaires as the evaluation tool. Therefore, studies such as ours that analyze the effects of HB training in CAI participants using the YBT, isokinetic strength test, and hop tests are rare. However, our study has the following limitations. We did not include a control group. Participants were non-professional athletes who played at least once a week, and visited a sports rehabilitation center for exercise therapy. Therefore, not providing participants with rehabilitation training for research purposes may be an ethical issue. The classification of the two groups reflected the preferences and needs of the participants. Therefore, there may be intergroup characteristics regarding exercise participation and rehabilitation training practice which were not considered in this study. Moreover, physical activities other than the suggested training could not be restricted or controlled. Last, since the study was conducted at a single institution, it cannot be excluded that regional, cultural, lifestyle, and socioeconomic characteristics could have a potential impact.

5. Conclusions

The 6-week rehabilitation program followed by the CB training group and the HB training group improved muscle strength, balance, lower extremity function, and subjective ankle satisfaction in both groups. Specifically, strength and lower extremity function evaluation were effective in both groups, but the CB training group showed greater improvement in high-speed angular velocity strength, triple hop, crossover hop, and 6 m hop test results compared to the HB training group. The recovery effect of balance and subjective satisfaction was the same in both groups. Therefore, HB training is recommended for CAI participants who have difficulty visiting the center and may be an appropriate alternative.

Abbreviations

BMI, body mass index; CAI, chronic ankle instability; CB, center-based; COVID-19, coronavirus disease; FAOS, foot and ankle outcome score; HB, home-based; ANOVA, analysis of variance; YBT, Y-balance test; FAAM, Foot and Ankle Ability Measure; LEFS, Lower Extremity Functional Scale.

Author contributions

QJ and YHK conceptualized the study; QJ devised the methodology; YHK and QJ performed the formal analysis; QJ and JKH conducted the investigation; QJ wrote and prepared the original draft; YHK reviewed and edited the manuscript; JKH analyzed the results using the software; and YHK and JKH provided supervision. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

The study was approved by the researcher's Institutional Review Board center (approved number: GWNU IRB 2021-13) and conducted in accordance with the Helsinki Declaration. All patients provided written informed consent.

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Conflict of interest

The authors declare no conflict of interest.

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