



EFFECTS OF MODIFIED STATION TRAINING ON PAIN, BALANCE, LOWER LIMB MUSCLES STRENGTH AND AGILITY IN ATHLETES WITH CHRONIC ANKLE INSTABILITY

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Abstract:

Ankle sprains are a common injury in athletes and have a high recurrence rate which can develop into chronic ankle instability (CAI). This leads to decreased balance, weakened lower limb strength and impaired agility, raising the risk of re-injury and adversely affecting athletic performance. Therefore, a suitable training program is necessary for injury prevention and enhancing sports performance. This study aimed to examine the effect of modified station training on pain, balance, lower limb muscle strength, and agility in athletes with chronic ankle instability after 8 weeks of training. **Methods:** The participants consisted of 40 athletes from Mahasarakham University and the National Sports University, Mahasarakham Campus, aged 18–25 years. They were purposively sampled and divided equally into two groups by simple random sampling to match the groups. Group 1 was the experimental group with a modified station training program and group 2 was the control group with a normal training program. The training program lasted for 8 weeks, with training sessions conducted 3 times per week. The outcome measurements included pain score measured as the numeric rating scale (NRS), static balance using a balance & stability test, dynamic balance measured by the star excursion balance test, muscle strength was assessed using the manual muscle test (MMT) which evaluated muscle strength based on a standardized grading scale and the Illinois agility test. **Results:** After an 8-week training program, both groups exhibited decreases in pain and increases in static balance, dynamic balance, lower limb muscle strength, and agility ($p < 0.05$). Additionally, the experimental group presented enhanced static balance, dynamic balance, and lower limb muscle strength compared to the control group. However, there was no significant improvement in pain and agility in comparison to the control group. **Conclusions:** The modified station training program improves physical

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performance in athletes with chronic ankle instability, promoting a safer and more effective return to sports.

Keywords: modified station training, pain, balance, lower limb strength, agility, chronic ankle instability

1. Introduction

Chronic ankle instability is a condition that develops following a lateral ankle sprain and is characterized by recurrent "giving way" or "twisting" of the ankle and a feeling of ankle instability for more than a year after the initial injury (Hertel & Corbett, 2019; Konphet & Siriphorn, 2024) along with a history of at least two sprains within the past six months (Guo *et al.*, 2024). The condition is common in athletes, with reports indicating that approximately 40% of those who have had an ankle sprain will develop ankle instability and about 25% of those who had their first ankle sprain (Gribble *et al.*, 2013). Recurrent ankle sprains result from damage to the ligaments around the ankle, muscles, and long-term limitations in joint function (Donovan *et al.*, 2020; Kamran *et al.*, 2026).

These impairments result in a reduced ability to maintain balance both at rest and in motion due to loss of efficiency of sensory receptors in the ligaments and ankles after injury and delayed reflexes for postural adjustment (Guo *et al.*, 2024; Su *et al.*, 2024). At the same time, there is a decrease in strength of the lower limb muscles, particularly the muscles around the ankle, which play an important role in force generation, shock absorption, alignment control, and ankle stabilization during weight-bearing (Luan *et al.*, 2021). These impairments affect the ability to perform agile movements such as acceleration, slowing down, stopping, and making rapid changes in direction, and can reduce the effectiveness of motion control (Choi *et al.*, 2023; Su *et al.*, 2024; Wikstrom *et al.*, 2021).

A review of the literature reveals that exercise and physical training are crucial components of rehabilitation approaches for individuals with chronic ankle instability, particularly balance training, strength training, and neuromuscular control training. These play a vital role in improving postural control, balance ability, and ankle and lower limb function (Luan *et al.*, 2021). Furthermore, empirical evidence from systematic reviews and meta-analysis shows that balance training can promote dynamic balance control, reduce ankle instability levels, and improve functional activity in individuals with CAI. Strength training, on the other hand, is significant for improving muscle performance, joint stability, and lower limb movement control (Mollà-Casanova *et al.*, 2021). Additionally, meta-analytic and systematic review evidence suggests that balance training is effective in improving dynamic balance, alleviating symptoms of ankle instability, and enhancing functional outcomes in individuals with CAI. Such training enables athletes to more effectively control body position and weight transfer, particularly in situations involving single-leg standing, reaching, or movement in multiple directions, as well as changes in body position during movement. This

contributes to improved joint positional awareness and movement control in athletes with chronic ankle instability. It can also enhance the muscles' ability to generate force and support the lower limbs, leading to improved balance, strength and athletic ability in athletes with chronic ankle problems (Cruz-Diaz *et al.*, 2015; Kalra *et al.*, 2021; Mohammadi Nia Samakosh *et al.*, 2022).

Exercise rehabilitation is a key approach recommended for athletes with chronic ankle instability (CAI). Important training components include balance training, lower limb muscle strengthening, and agility training. Balance training can improve postural control and movement ability, while strength training enhances the functional capacity of the muscles surrounding the ankle and lower limbs, and agility training promotes the ability to control rapid directional changes. However, CAI is associated with multiple interconnected impairments. Therefore, focusing on only one component may not comprehensively address the performance limitations of athletes with CAI. Developing a multi-component training program may be more appropriate for meeting the rehabilitation needs of athletes with CAI (Guo *et al.*, 2024; Mollà-Casanova *et al.*, 2021; Setyawan *et al.*, 2021; Su *et al.*, 2024).

Modified station training is an attractive training format because it can integrate multiple training components within a single program and adapt activities at each station to the limitations and needs of athletes with CAI. It aims to develop performance skills crucial for sports, such as body control while standing or bearing weight on one leg. This improves movement control and weight transfer, especially during reaching, stretching, and changing direction. Combined with enhanced ankle support and force generation capabilities during movement, athletes can move, change direction, and react to various sports situations more quickly and efficiently.

Therefore, this study developed a modified station training program, adapting exercises at each station to focus on improving balance, lower limb strength, and agility. The objective of this study was to investigate the effect of an 8-week modified station training program on balance, lower limb strength, and agility in athletes with CAI.

2. Material and Methods

This study employed a quasi-experimental research design with a two-group pretest-posttest approach. Participants were recruited using purposive sampling based on predefined inclusion and exclusion criteria. All participants completed the approved informed consent procedures mandated by the Institutional Review Board on Human Research of Mahasarakham University, Thailand (No. 234-797/2025). Participants included college athletes who rely primarily on their lower limbs for acceleration, deceleration, and change of direction, such as futsal players, soccer players, and volleyball players. The sample size was calculated using Utilizing G*Power (version 3.1.9.4) with an effect size estimate of 0.9 and alpha and beta levels set at 0.05 and 0.80, respectively (Brydges, 2019; Naderi & Ahi, 2025). Based on these values, the required sample size was 42 participants. To avoid the 10% dropout rate, a total sample size of 46

individuals was chosen. Following 8 weeks of training, 6 participants withdrew due to inability to adhere to the schedule and lack of follow-up, resulting in a final sample size of 40 individuals. They were recruited and equally assigned to an experimental group ($n = 20$) and a control group ($n = 20$). The experimental group participated in a modified station training program, while the control group continued with normal program training. The inclusion criteria are as follows: (1) The age range is 18–25 years (2) participants had experienced CAI on one side within the 6 months prior to the study (3) CAI with a pain intensity score of 3 to 7 on the numerical response scale (NRS) (Chen *et al.*, 2022). (4) CAIT score must be < 24 .

The exclusion criteria are as follows:

- 1) Participants are presently participating in any ankle-related rehabilitation activities
- 2) Injuries such as fractures or surgical procedures to the lower extremity, as well as other muscular, joint, or neurological conditions that impact lower limb function
- 3) Cognitive, vestibular, and visual impairments resulting from neurological and vestibular conditions.

2.1 Procedure

All participants were informed about the procedures of the experiment and its implications. They were divided into 2 groups: the experimental group and control group. Both groups underwent pretest and posttest assessments, which included (1) numerical rating scale (NRS); (2) balance & stability test; (3) star excursion balance test; (4) manual muscle test; and (5) Illinois agility test (Sarvestan *et al.*, 2018). A control group followed their normal training program for each sport, an approach routinely followed under the guidance of their team coach, including warm-up, sport-specific skills training, and simulated practice, with a duration of 1 hour. An experimental group underwent training with a 12-station modified training program. During a period of 8 weeks, divided into two intervals: Weeks 1-4: 5 minutes of stretching, 30 seconds of exercise at each station, 30 seconds of rest between stations, two sets, 1 minute of rest between sets, and a 5-minute cool-down for a total of one hour. Weeks 5-8: 5 minutes of stretching, 45 seconds of exercise at each station, 30 seconds of rest between stations, 3 sets, 1 minute of rest between sets, and a 5-minute cool-down, culminating in a total duration of 1 hour and 20 minutes.

The training was performed 3 times per week (Figure 1).

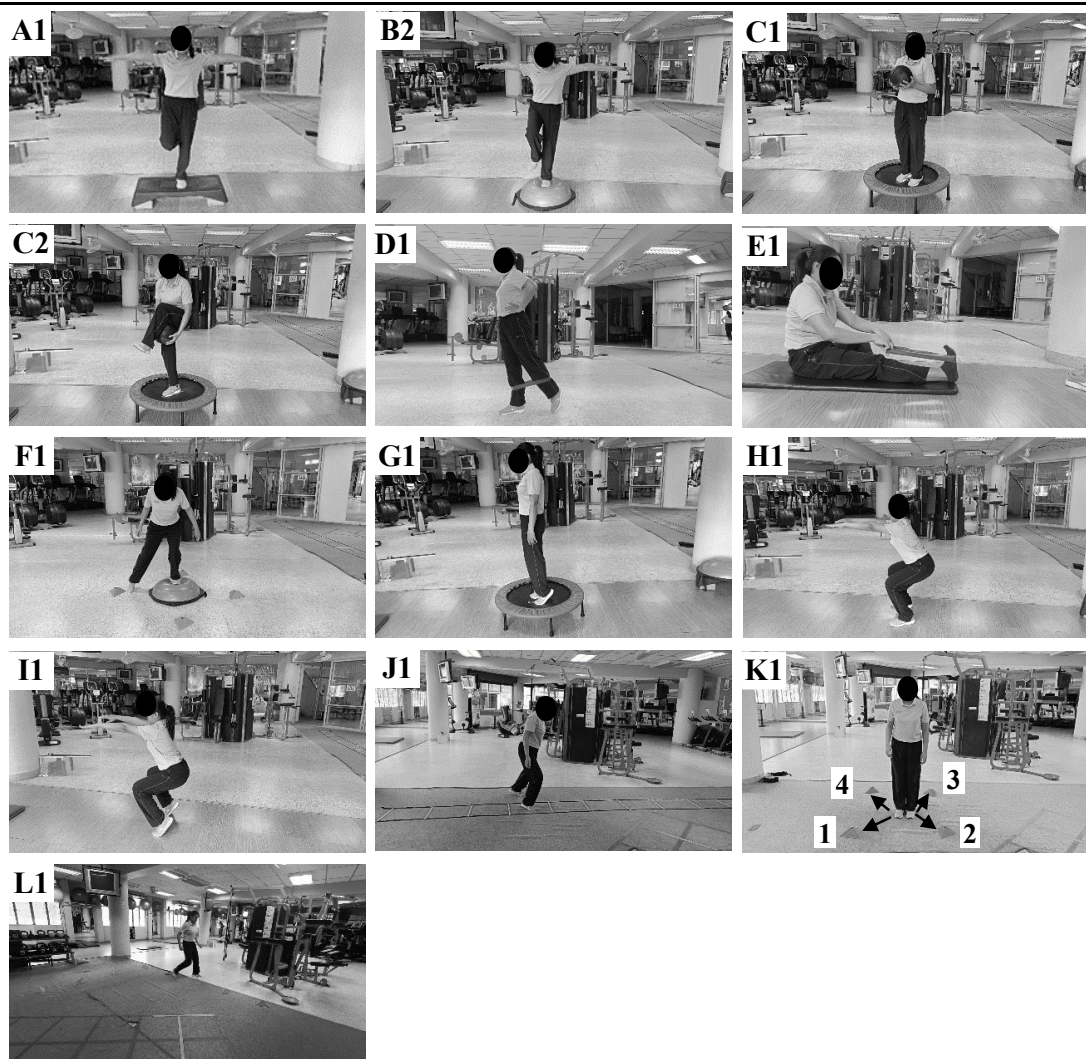


Figure 1: Single-leg stance on a stable surface (A1), Single-leg stance with knee lift on an unstable surface (B2), Single-leg stance with knee lift and under-leg ball pass on a mini trampoline (C1-C2). Backward leg kick with resistance band (D1), Ankle dorsiflexion and plantarflexion with resistance band (E1), Single-leg stance with three-direction toe touch on an unstable surface (F1), Single-leg heel raise on a mini trampoline (G1), Squat (H1), Squat with heel raise (I1), Agility ladder jumps (J1), Two-leg X-shaped jumps (K1), Zigzag L-shaped running (L1)

3. Results

3.1 Pain Assessment

Participants rated their local pain around the ankle joint using the numerical rating scale (NRS) on the affected side. NRS is divided into four levels: 0 (no pain), 1-3 (slight pain), 4-6 (moderate pain), and 7-10 (most severe pain). Participants were asked to rate their perceived ankle pain intensity, and the scores were recorded for statistical analysis.

3.2 Balance & Stability Test

The balance stability test uses a wobble board to assess static balance. The balance was done in a position suggested by Ahern *et al.*, 2021; participants were positioned on a wobble board with both feet, then pressed the start button. They must subsequently attempt to maintain balance for a duration of 30 seconds. Two trials were performed for each participant, and the best time was recorded (Ahern *et al.*, 2021) (Figure 2). Test-retest reliability was established by determining an instrument's capability of measuring a variable with consistency. Twenty volunteers with a mean age of 19.75 ± 1.16 years were recruited for the study. Before the study, the examiners participated in a familiarization training session for the balance stability test. The same examiner was randomized using a random sequence for each subject. The test was performed continuously for two days. The balance stability test was reliable (ICC =0.819).



Figure 2: Balance & stability test

3.3 Star Excursion Balance Test

Participants stood barefoot, hands on their hips, and one foot in the middle of a star. They extended one foot in a specified direction as far as possible, gently contacting the line before returning to the initial position. The supporting foot remained flat on the ground. Repeat this process for one complete cycle, touching the line in every direction reached. The test is invalid if the test subject fails to return to the starting position, touches the line too firmly, or loses balance. Three trials were performed for each foot. The average distance in each direction (cm) was used for data analysis (Phuaklikhit *et al.*, 2024).

3.4 Manual Muscle Test

Gastrocnemius and soleus muscles strength was examined while participants were performing maximum contraction. Participants stood on one leg with both hands positioned at waist level. Subsequently, elevated their heels from the floor consecutively through the maximum available range without pause between lifts and without feeling fatigue. MMT is performed in grading as follows: Grade 5 (Normal) Patient successfully completes a minimum of 25 heel rises through full range of motion without a rest between rises and without fatigue. Twenty-five heel rises represent approximately 60 percent of maximum electromyographic activity of the plantar flexors. Grade 4 (Good) Patient

completes any number of correct heel rises between 24 and 10 with no rest between repetitions and without fatigue. Grade 3 (Fair) Patient completes between nine and one heel rises correctly with no rest or fatigue. If the patient cannot complete at least one correct full-range heel rise in the standing position. Grade 2 (Poor) The patient can just clear the heel from the floor and cannot get up on the toes for the end test position. Grade 0 No muscle contraction is detected (Brown *et al.*, 2013).

3.5 Illinois Agility Test

The participants start from the starting point upon receiving the "Start" command. Start the stopwatch as they run 10 m forward to the far cone and turn around it. Run back toward the start area. Weave in and out through the four center cones. Final sprints: run 10 meters to the far cone, turn around it, and sprint 10 m back. Finish stopping the timing when crossing the finish line. Recorded in seconds. Each individual conducted two trials, with the higher outcome recorded (Sarvestan *et al.*, 2018).

3.6 Data Analysis

Data are reported as means $\pm$ standard deviations. Normality was tested with the Shapiro-Wilk and Levene tests. The paired t-test was applied in all groups to identify possible differences between the pre- and post-training periods, while unpaired t-tests were applied to compare differences between the experimental and control groups. All statistical tests were processed with the use of the SPSS statistical package (v. 26; SPSS Inc., Chicago, USA). Statistical significance was set at $p < 0.05$.

Table 1: Baseline characteristics of participants in the study (n = 40)

Variables	CG (n = 20) mean $\pm$ SD	EG (n = 20) mean $\pm$ SD	p-value ^a
Age (years)	19.75 $\pm$ 1.16	19.95 $\pm$ 1.10	0.302
Height (cm)	170.00 $\pm$ 8.17	169.10 $\pm$ 8.50	0.297
Weight (kg)	60.30 $\pm$ 4.41	60.35 $\pm$ 4.45	0.090
BMI (kg/m ²)	21.78 $\pm$ 1.40	21.87 $\pm$ 1.36	0.051
CAIT score	19.20 $\pm$ 2.65	19.45 $\pm$ 2.78	0.493

Note: EG - experimental group, CG - control group, BMI – body mass index, CAIT – Chronic Ankle Instability Tool.

^a independent t-test for baseline comparison

* Significance value set at $p < 0.05$.

The results are presented in Table 1. Forty participants were included in this study. 40 participants successfully completed the study protocol, excluding the two who decided not to participate. There were no significant differences between groups in age, height, weight, and BMI. Regarding CAIT score values, small variations between groups were observed. The CG also displayed a slightly higher average score than the EG.

Table 2: Comparison of outcome measurements between CG (n = 20)
and EG (n = 20) at baseline and 8-weeks post-intervention

Variables	Group	Baseline (mean $\pm$ SD)	8-weeks post (mean $\pm$ SD)	p-value (within group) ^a	p-value (between groups) ^b
NRS (score)	CG	2.15 $\pm$ 0.75	1.25 $\pm$ 0.44	0.001*	0.731
	EG	2.00 $\pm$ 0.46	1.30 $\pm$ 0.47	0.001*	
BST (second)	CG	17.80 $\pm$ 1.40	18.90 $\pm$ 1.07	0.004*	0.001*
	EG	16.51 $\pm$ 2.38	19.15 $\pm$ 0.94	0.000*	
SEBT (cm)	CG	76.37 $\pm$ 7.20	82.16 $\pm$ 4.99	0.001*	0.034*
	EG	78.83 $\pm$ 9.83	87.96 $\pm$ 10.69	0.003*	
MMT (grade)	CG	4.20 $\pm$ 0.78	4.60 $\pm$ 0.50	0.042*	0.001*
	EG	4.55 $\pm$ 0.51	4.80 $\pm$ 0.71	0.001*	
IAT (second)	CG	18.76 $\pm$ 1.31	18.14 $\pm$ 1.10	0.042*	0.533
	EG	19.85 $\pm$ 0.85	18.35 $\pm$ 1.08	0.002*	

Note: Numerical Rating Scale: NRS (score), Balance & Stability test (second), Star Excursion Balance Test (cm), Manual Muscle Test (grade), Illinois Agility Test (second)

^a paired t-test for within-group comparison, ^b independent test for between-groups comparison

* Significance value set at $p < 0.05$.

After an eight-week intervention, the results indicated that both groups exhibited significant improvement in all variables post-intervention compared to pre-intervention ($p < 0.05$). No statistically significant differences were found between groups in pain and agility; the EG demonstrated no statistically significant results in the NRS and the IAT compared to the CG. Additionally, the EG demonstrated significant enhancements in static balance, dynamic balance and gastrocnemius muscle strength compared to the CG ($p < 0.05$).

4. Discussion

4.1 Pain

After 8 weeks of training, both the experimental and control groups showed a statistically significant reduction in pain. This finding suggests that regular exercise training may contribute to improvements in pain among athletes with chronic ankle instability (CAI). In the experimental group, the modified station training program incorporated balance exercises, movement-control activities, and exercises performed on unstable surfaces. These training components may have contributed to improvements in ankle stability and neuromuscular control, which could have helped reduce pain. Previous studies have also reported beneficial effects of exercise-based interventions on pain and functional outcomes in individuals with CAI (Wagemans *et al.*, 2023; Zhang & Zhang, 2023). The control group, which participated in standard sport-specific training, also demonstrated a significant reduction in pain. This improvement may be related to the variety of movements and physical demands involved in regular sport training, which may provide sufficient stimuli for maintaining proprioception, muscular function, and neuromuscular coordination. These adaptations may contribute to improved ankle function and

tolerance to physical activity (Abbasi *et al.*, 2023; Yang *et al.*, 2025). However, no statistically significant difference in pain was observed between the experimental and control groups after the intervention. This finding indicates that the modified station training program did not demonstrate a clear additional benefit over standard sport-specific training for reducing pain within the 8-week intervention period. One possible explanation is that both training programs involved regular physical activity and movements that may contribute to improvements in ankle function. In addition, the 8-week intervention period may have been insufficient to produce a detectable difference between the two training approaches.

4.2 Exercise Training, Static and Dynamic Balance

After 8 weeks of training, the experimental group demonstrated significant improvements in both static and dynamic balance. These findings suggest that the modified station training program may contribute to improved balance control and functional ankle stability in athletes with chronic ankle instability. The program incorporated exercises performed on both stable and unstable surfaces, together with single-leg balance and movement-control activities. These exercises may have challenged postural control and neuromuscular coordination, potentially improving the ability to maintain body position and respond to changes in ankle position during both stationary and dynamic tasks. Similar improvements in balance following exercise-based interventions in athletes with chronic ankle instability have also been reported (Naderi & Ahi, 2025; Yesilkir & Ergezen Sahin, 2025).

The control group also demonstrated significant improvements in static and dynamic balance after the intervention. This improvement may be related to the nature of regular sport-specific training, which involves repeated changes in body position, movement direction, and balance control during sport-related activities. Repeated exposure to these movements may provide sufficient stimuli to maintain and improve postural control and balance performance. However, no significant differences were observed between the experimental and control groups after the 8-week intervention. This finding indicates that, although the modified station training program was associated with significant within-group improvements in balance, its effects were not statistically superior to those of regular sport-specific training. Therefore, the improvements observed in the experimental group should be interpreted as evidence that modified station training may be a useful approach for improving balance in athletes with chronic ankle instability, rather than evidence that it is more effective than conventional sport-specific training. The relatively short intervention period and the balance-related demands already present in regular sports training may have contributed to the lack of a significant between-group difference.

4.3 Lower Limb Muscle Strength

After 8 weeks of training, the experimental group demonstrated a statistically significant improvement in lower limb muscle strength. This finding suggests that the modified

station training program may have contributed to improvements in lower limb muscle function in athletes with chronic ankle instability. The program combined exercises involving unstable surfaces, toe raises, squats, and resistance exercises, which required repeated activation and coordination of the muscles involved in ankle and lower limb control. These exercises may have enhanced neuromuscular coordination and the ability to generate force during functional movements, particularly involving the peroneal muscles, tibialis anterior, gastrocnemius, soleus, quadriceps, and hamstrings. Similar improvements in lower limb strength following combined balance and strength training have been reported in athletes with chronic ankle instability (Mohammadi Nia Samakosh *et al.*, 2022; Wikstrom *et al.*, 2021).

The control group also demonstrated a statistically significant improvement in lower limb muscle strength. This improvement may be related to their regular sport-specific training, which included activities such as running, acceleration, jumping, and changes of direction. Repeated performance of these movements may provide sufficient muscular loading and neuromuscular stimulation to support improvements in lower limb strength. However, the specific contribution of individual components of the sport-specific training cannot be determined from the present study (Ahern *et al.*, 2021; Young *et al.*, 2022).

Importantly, the between-group comparison showed a statistically significant difference in lower limb muscle strength, with greater improvement observed in the experimental group. This finding suggests that the modified station training program may provide additional benefits for lower limb muscle strength compared with regular sport-specific training. The possible advantage may be related to the structured combination of balance, resistance, and functional lower limb exercises performed with consistent training conditions.

4.4 Agility

After 8 weeks of training, the experimental group showed a statistically significant improvement in agility. This finding suggests that the modified station-based training program may have contributed to improved agility performance. The program incorporated specific movement activities, including agility ladder jumps, X-shaped two-legged jumps, and L-shaped zigzag running, which required participants to repeatedly control body position and movement while changing direction. These activities may have provided opportunities to practice rapid changes in movement direction and body control, thereby contributing to improved agility performance (Sarvestan *et al.*, 2018; Seyhan *et al.*, 2026).

The control group, which participated in standard sport-specific training, also demonstrated a statistically significant improvement in agility. This may be explained by the dynamic nature of sport-specific activities, which require athletes to continuously adjust their movement speed, rhythm, body position, and direction in response to different movement situations. Such activities may provide sufficient stimulus for maintaining and developing agility during regular training. However, no statistically

significant difference was observed between the experimental and control groups. Therefore, the findings do not demonstrate that the modified station-based training program was superior to standard sport-specific training for improving agility. One possible explanation is that both training programs involved continuous movement and changes in direction, providing similar neuromuscular and movement-control demands. In addition, the 8-week training period may not have been sufficient to produce a clear difference in agility between the two training approaches.

5. Conclusions

An eight-week modified station training program improved selected physical fitness outcomes, particularly static and dynamic balance and lower-limb muscle strength. Additionally, modified station training appears to be a promising strategy for facilitating rehabilitation and improving selected physical fitness components in athletes with chronic ankle instability.

Authors' Contributions

Sawittri Songsuk participated in conceptualization, selection of volunteers, methodology, data curation and collection, and writing the original draft. Archrawadee Srijaroon was involved in conceptualization, analysis, and interpretation of the data, supervision, and critically revised the manuscript for important intellectual content.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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References

- Abbasi, L., Panahi, F., Zarei-Kurdshooli, Z., & Yahya-Abadi, F. Y. (2023). The effect of perturbation training with and without applying dry needling on leg muscles in patients with chronic ankle sprain. *Journal of Bodywork and Movement Therapies*, 35, 233-237. <https://doi.org/10.1016/j.jbmt.2023.04.044>
- Ahern, L., Nicholson, O., O'Sullivan, D., & McVeigh, J. G. (2021). Effect of functional rehabilitation on performance of the star excursion balance test among recreational athletes with chronic ankle instability: a systematic review. *Archives of rehabilitation research and clinical translation*, 3(3), 100133. <https://doi.org/10.1016/j.arrct.2021.100133>
- Brown, M., Hislop, H., & Avers, D. (2013). *Daniels and Worthingham's Muscle Testing-E-Book: Daniels and Worthingham's Muscle Testing-E-Book*. Elsevier Health Sciences.
- Brydges, C. R. (2019). Effect size guidelines, sample size calculations, and statistical power in gerontology. *Innovation in aging*, 3(4), igz036. <https://doi.org/10.1093/geroni/igz036>
- Chen, Y., Cao, S., Qian, L., Chen, W., Wang, C., Ma, X., Wang, X., & Huang, J. (2022). The influence of local pain on balance control in patients with chronic ankle instability. *BMC Musculoskeletal Disorders*, 23(1), 699. <https://doi.org/10.1186/s12891-022-05656-4>
- Choi, J. Y., Yoo, T., Burcal, C. J., & Rosen, A. B. (2023). Dual-task differences in individuals with chronic ankle instability: A systematic review with meta-analysis. *Gait & Posture*, 106, 28-33. [doi: 10.1016/j.gaitpost.2023.08.013](https://doi.org/10.1016/j.gaitpost.2023.08.013)
- Cruz-Diaz, D., Lomas-Vega, R., Osuna-Pérez, M., Contreras, F., & Martínez-Amat, A. (2015). Effects of 6 weeks of balance training on chronic ankle instability in athletes: a randomized controlled trial. *International journal of sports medicine*, 754-760. [doi: 10.1055/s-0034-1398645](https://doi.org/10.1055/s-0034-1398645).
- Donovan, L., Hetzel, S., Laufenberg, C. R., & McGuine, T. A. (2020). Prevalence and impact of chronic ankle instability in adolescent athletes. *Orthopaedic journal of sports medicine*, 8(2), 2325967119900962. <https://doi.org/10.1177/2325967119900962>
- Gribble, P. A., Delahunt, E., Bleakley, C., Caulfield, B., Docherty, C., Fourchet, F., Fong, D., Hertel, J., Hiller, C., & Kaminski, T. (2013). Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the

- International Ankle Consortium. *Journal of orthopaedic & sports physical therapy*, 43(8), 585-591. <https://www.jospt.org/doi/10.2519/jospt.2013.0303>
- Guo, Y., Cheng, T., Yang, Z., Huang, Y., Li, M., & Wang, T. (2024). A systematic review and meta-analysis of balance training in patients with chronic ankle instability. *Systematic reviews*, 13(1), 64. <https://doi.org/10.1186/s13643-024-02455-x>
- Hertel, J., & Corbett, R. O. (2019). An updated model of chronic ankle instability. *Journal of Athletic Training*, 54(6), 572-588. doi: [10.4085/1062-6050-344-18](https://doi.org/10.4085/1062-6050-344-18)
- KALRA, S., Pal, S., Pawaria, S., & Yadav, J. (2021). Comparative Study of Wobble Board and Bosu Ball along with Strength Training on Lower Limb Strength, Dynamic Balance, Agility and Functional Performance of Runners with Lateral Ankle Instability. *Journal of Clinical & Diagnostic Research*, 15(5). doi: [10.7860/jcdr/2021/46588.14820](https://doi.org/10.7860/jcdr/2021/46588.14820)
- Kamran, S., Nadeem, Z., Baig, M., Arif, M. A., Fayyaz, A., Ahmed, A., Zaidi, A., Khan, M., Bashar, A., & Khan, R. (2026). Prevalence and Impact of Chronic Ankle Instability Among Recreational Athletes During Amateur Sports Programs in Collegiate. *Journal of Health, Wellness and Community Research*, 1-10. <https://doi.org/10.61919/9vtm9652>
- Konphet, N., & Siriphorn, A. (2024). Textured mat influence on muscle activity and balance strategies for chronic ankle instability. *Human Movement*, 25(4), 68-78. <https://doi.org/10.5114/hm/194015>
- Luan, L., Adams, R., Witchalls, J., Ganderton, C., & Han, J. (2021). Does strength training for chronic ankle instability improve balance and patient-reported outcomes and by clinically detectable amounts? A systematic review and meta-analysis. *Physical Therapy*, 101(7), pzab046. <https://doi.org/10.1093/ptj/pzab046>
- Mohammadi Nia Samakosh, H., Brito, J. P., Shojaedin, S. S., Hadadnezhad, M., & Oliveira, R. (2022). What Does Provide Better Effects on Balance, Strength, and Lower Extremity Muscle Function in Professional Male Soccer Players with Chronic Ankle Instability? Hopping or a Balance Plus Strength Intervention? A Randomized Control Study. A Randomized Control Study. <https://doi.org/10.3390/healthcare10101822>
- Mollà-Casanova, S., Inglés, M., & Serra-Añó, P. (2021). Effects of balance training on functionality, ankle instability, and dynamic balance outcomes in people with chronic ankle instability: systematic review and meta-analysis. *Clinical Rehabilitation*, 35(12), 1694-1709. <https://doi.org/10.1177/02692155211022009>
- Naderi, A., & Ahi, K. (2025). Comparative analysis of land-based vs. water-based balance training on quality of life and physical and psychological deficits in athletes with chronic ankle instability: a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), 9. <https://doi.org/10.1186/s13102-024-01049-3>
- Phuaklikhit, C., Junsri, T., Saito, S., Muraki, S., & Loh, P. Y. (2024). Biomechanical and physiological variables in dynamic and functional balance control during Single-

- Leg loading in individuals with chronic ankle instability: A scoping review. *Sports*, 12(8), 224. <https://doi.org/10.3390/sports12080224>
- Sarvestan, J., Alaei, F., Kazemi, N. S., Khial, H. P., Shirzad, E., & Svoboda, Z. (2018). Agility profile in collegiate athletes with chronic ankle sprain: the effect of Athletic and Kinesio taping among both genders. *Sport Sciences for Health*, 14, 407-414. <https://doi.org/10.1007/s11332-018-0453-2>
- Setyawan, R., Setijono, H., & Kusnanik, N. W. (2021). The Effect of Floor and Swiss Ball Exercises Using Circuit Training Methods towards Balance, Strength, Flexibility and Muscle Endurance. *Britain International of Humanities and Social Sciences (BioHS) Journal*, 3(2), 384-395. <https://doi.org/10.33258/biohs.v3i2.469>
- Seyhan, S., Acar, G., Bilici, M. F., Girginer, F. G., Bilici, O. F., & Soylu, C. (2026). Injury prevention relevance: markerless functional performance testing in athletes with chronic ankle instability to inform recurrent sprain risk screening. *BMC Sports Science, Medicine and Rehabilitation*. <https://doi.org/10.1186/s13102-026-01670-4>
- Su, Y., Li, W., Pan, C., & Shi, Y. (2024). Effects of combination of strength and balance training on postural control and functionality in people with chronic ankle instability: a systematic review and meta analysis. *BMC Sports Science, Medicine and Rehabilitation*, 16(1), 79. <https://doi.org/10.1186/s13102-024-00845-1>
- Wagemans, J., Bleakley, C., Taeymans, J., Kuppens, K., Schurz, A. P., Baur, H., & Vissers, D. (2023). Rehabilitation strategies for lateral ankle sprain do not reflect established mechanisms of re-injury: A systematic review. *Physical Therapy in Sport*, 60, 75-83. <https://doi.org/10.1016/j.ptsp.2023.01.008>
- Wikstrom, E. A., Cain, M. S., Chandran, A., Song, K., Regan, T., Migel, K., & Kerr, Z. Y. (2021). Lateral ankle sprain and subsequent ankle sprain risk: a systematic review. *Journal of Athletic Training*, 56(6), 578-585. [doi: 10.4085/1062-6050-168-20](https://doi.org/10.4085/1062-6050-168-20)
- Yang, Y., Wu, Y., & Zhu, W. (2025). Recent advances in the management of chronic ankle instability. *Chinese Journal of Traumatology*, 28(01), 35-42. <https://doi.org/10.1016/j.cjtee.2024.07.011>
- Yesilkir, S., & Ergezen Sahin, G. (2025). Dynamic neuromuscular stabilization, balance, and conventional training for chronic ankle instability in amateur athletes: a randomised controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), 286. <https://doi.org/10.1186/s13102-025-01319-8>
- Young, K. L., Morris, B., & Herda, T. J. (2022). The role of strength and conditioning in the prevention and treatment of chronic lateral ankle instability. *Strength & Conditioning Journal*, 44(2), 61-75. <https://doi.org/10.1519/SSC.0000000000000648>
- Zhang, Z., & Zhang, M. (2023). Effect of different ankle braces on lower extremity kinematics and kinetics following special-induced fatigue for volleyball players with functional ankle instability. *Heliyon*, 9(6). <https://doi.org/10.1016/j.heliyon.2023.e16380>