2023, Volume 3 (Issue 1): 4 OPEN ACCESS

The Effects of a Novel Lateral Ankle Strengthening Program in NCAA Division III Football Players

Original Research

Jeff Buxton, CJ Otwell, Jack Petit, Holton Gwaltney, Nikolas Grabiec, Samuel Luithle, Hayden Gerhart, Philip Prins[1]

[1]*Department of Exercise Science, Grove City College, Grove City, PA*

Open Access

Published: March 16, 2023

Research Directs in Strength and Performance: *2023, Volume 3 (Issue 1): 4*

ISSN: 2768-5187

Abstract

Introduction: Lateral ankle sprains (LAS) are among the most reported injuries in college athletics, typically resulting from excessive closed-kinetic chain (CKC) supination. The purpose of this study was to compare the effects of a novel CKC supination-style ankle strengthening program to a traditional ankle strengthening program on common LAS indices.

Methods: Thirty NCAA Division III collegiate football players (19.9±1.0yrs., 182.2±6.9cm, 98.8±18.0kg) were randomly assigned to a novel exercise (SUP, n = 16) or traditional exercise group (TRA, n = 14). The SUP group performed dynamic bodyweight exercises with controlled ankle supination while the TRA group performed traditional ankle strengthening exercise using elastic bands and stability exercises 3 times per week for 6 weeks. Right and left ankle inversion (InvR, InvL) and eversion (EvR, EvL) strength (kg), ankle inversion range of motion (romR, romL) (deg.), and figure-8 hop test (fig8R, fig8L) (s) performance were assessed pre- and post-intervention.

Results: Both groups showed significant improvements in all outcome measures pre- to post-test (ΔInvR: TRA 4.5±4.3kg, SUP 5.0±4.4kg; ΔIvL: TRA 4.0±3.8kg, SUP 4.8±3.6kg; ΔEvR: TRA 5.7±4.3kg, SUP 4.7±3.3kg; ΔEvL: TRA 4.7±2.9kg, SUP 4.5±2.2kg; ΔromR: TRA 4.5±2.6°, SUP 4.9±3.0°; ΔromL: TRA 4.7±4.5°, SUP 4.6±5.1°; Δfig8R: TRA -0.43±0.20s, SUP -0.37±0.31s; Δfig8L: TRA -0.40±0.22s, SUP -0.34±0.30s; p's<0.001), with no difference between groups.

Conclusions: A bodyweight, supination style ankle training program can improve physical qualities related to LAS to a similar extent as a traditional program, and therefore, could potentially be a viable alternative strategy for reducing LAS in Division III NCAA football players.

Key Words: lower extremity injury, dynamic balance, athletic injuries.

Corresponding author: Jeff Buxton, buxtonjd@gcc.edu

Introduction

Ankle injuries are among the most prevalent musculoskeletal injuries reported worldwide [1] with at least one to two ankle sprains per 1000 exposures daily in Western countries [1,2]. The incidence of ankle injuries is even higher in competitive sports with a reported range of 0.88 to 7 ankle sprains per 1000 exposures, with court sports accounting for the highest [1,3] followed by select field sports. Overall, evidence suggests that ankle sprains account for 20-40% of all athletic injuries. A recent report found that basketball, soccer and football had the highest ankle sprain rates, with football showing the largest proportion of ankle sprains overall [4]. Regarding football, participation in National Collegiate Athletic Association (NCAA) football remains popular and continues to rise annually [5]. Between 2015 and 2018 ankle injuries were among the largest proportion (12.5%) of all injuries reported at all levels of collegiate football, including lateral ankle sprains (LAS) at 6.9% of injuries [5]. As participation in football and other sports continues to rise the prevalence of ankle injuries would be expected to increase as well supporting the need to identify potential strategies for reducing such injuries.

LAS may occur through direct contact, indirect contact or noncontact resulting in excessive subtalar inversion and internal rotation, and causing damage to tendons, muscles (e.g., peroneals), and ligaments (e.g., subtalar lateral talocalcaneal, cervical, bifurcate, and interosseous talocalcaneal) on the lateral side of the ankle [6–8]. Research indicates that a precise balance between ankle mobility and stability are required for optimal ankle performance and injury avoidance [8]. Although mixed, some evidence suggests that ankle joint laxity (leading to excessive supination), and ankle strength imbalances may be predictors of LAS [8–14]. Additionally, it has been suggested that mal-adjustments to whole body mechanics (e.g., excessive pelvis and hip excursion) precede LAS [7], implying that dynamic whole body postural control as well as foot and ankle mechanics play a role in LAS. Understanding these mechanisms provides insight into developing clinical treatments as well as potential injury reduction programs.

LAS injury prevention programs are commonly found within pre-activity warmups and team strength and conditioning sessions [15]. Stretching, strengthening, stability, and sport-specific hopping and agility exercises are the most common elements of LAS prevention programs [15–17]. The nature of the exercises included in these interventions are such that they may aid in reduction of injuries across multiple joints [18,19]. However, a challenge with this traditional approach is the time commitment and resources, in the form of equipment and space, to address each of the prior elements, which may lead to poor compliance [19]. An additional consideration is the ability of prevention programs to successfully enhance ankle joint and whole body neuromuscular control to prepare for injurious joint loading [15,20], which is often not possible with the traditional approach.

An alternative approach, using dynamic standing bodyweight movements with controlled supination of the ankle, may present a viable option for enhancing ROM, strength, and neuromuscular control indices related to LAS without the constraints of space, equipment, and time. Therefore, the purpose of this study is to compare a traditional LAS injury prevention protocol with a novel dynamic supination-style protocol on ankle inversion ROM, local ankle muscular strength, stability and agility. We hypothesized that both the traditional and novel protocols will improve maximum ankle ROM, inversion and eversion strength, and 1-leg figure 8 hopping ability over the course of a 6-week training program.

Scientific Methods

A randomized parallel groups design was used to compare the impact of a traditional style and a novel supination-style lateral ankle strengthening exercise program on active ankle inversion ROM, lateral ankle strength, and dynamic stability and agility in 30 NCAA Division III collegiate football players. Inversion ROM, peak ankle inversion & eversion isometric force, and a 1-leg figure-8 hop test were tested before and after a 6-week intervention. The traditional style program used resistance band exercises for the ankles and hips and single leg hopping drills, while the novel program incorporated standing dynamic bodyweight movements with controlled ankle supination exercises. All procedures were approved by the Grove City College Institutional Review Board prior to implementation and were conducted in the Grove City College Exercise Science Laboratory.

Participants

A convenience sample of 30 NCAA Division III football players (19.9±1.0 yrs., 182.2±6.9 cm, 98.8±18.0 kg) volunteered to participate in this study (Table 1). Participants were excluded if they had 1) a current musculoskeletal injury including recent ankle injury within the previous 6 months and 2) known cardiovascular, metabolic, or respiratory conditions. Following familiarization participants were randomly assigned to either the traditional style exercise program (TRA; n=14) or the novel supination-style exercise program (SUP; n=16). All participants were instructed to refrain from vigorous physical activity for at least 24 hours prior to each testing session, to maintain their regular team strength and conditioning, without engaging in any additional training and to maintain their normal diet throughout the study. At baseline, there were no differences in subject characteristics (age, stature, body mass, BMI, etc.) (Table 1).

Table 1. Physical Characteristics (mean ± SD) of Participants (N=30)

Variables	TRA (N=14)	SUP (N=16)	*p*-value
Age (yrs.)	19.78 ± 0.97	19.94 ± 1.12	0.698
Stature (cm)	179.82 ± 7.06	184.22 ± 6.28	0.082
Mass (kg)	95.78 ± 17.80	101.36 ± 18.36	0.407
BMI (kg•m^{-2})	28.92 ± 3.98	29.82 ± 5.27	0.607
%BF	20.67 ± 7.74	20.86 ± 7.77	0.945
Fat mass (kg)	20.04 ± 9.84	22.38 ± 11.83	0.564
FFM (kg)	75.74 ± 9.07	79.34 ± 7.06	0.231

BMI, body mass index; %BF, body fat percentage; FFM, fat free mass

Protocol

Familiarization Session

Participants received an overview of the study protocols and completed a health history questionnaire and informed consent after being made aware of the risks of participation. Anthropometric assessments including stature (cm), body mass (kg), fat free mass (kg) and fat mass (% and kg) were then collected. Stature was measured using a physician's scale (Detecto, Webb City, MO). Body mass and body composition (fat and lean mass) was measured using a Tanita bioelectrical impedance analyzer (BIA) (MC-980Uplus, Tanita Corporation of America, Arlington Heights, Illinois). The weight of the subject's shorts and t-shirt was estimated at 0.5 kg and entered into the BIA. Participants were instructed to remove their socks and shoes and then to stand on the BIA for approximately 30 seconds until the analysis was complete. Participants were then oriented to each of the ROM, strength, and figure-8 hop tests as well as each of the exercises in the TRA and SUP programs.

Pre- and Post-testing Battery

Participants completed tests of active ankle inversion ROM, maximal voluntary isometric contraction (MVIC) for ankle inversion and eversion, and the 1-leg figure-8 hop test. Three trials of each test were completed on both right and left legs with the average of each of those trials used for data analysis.

Active ankle inversion ROM. A flexible goniometer (Baseline 360° Goniometer, Fabrication Enterprise, Elmsford, NY) was used to determine each subject's active ankle inversion ROM for both right and left legs (romR & romL, respectively). Participants were asked to sit on a training table with the foot and ankle of the testing leg hanging off the table in a neutral position not favoring dorsiflexion or plantarflexion. Once in this position, the pivot of the goniometer was positioned anteriorly on the middle of the talus bone. The superior (stationary) arm was in line with the tibia and the inferior (moving) arm was aligned with the second metatarsal bone. Participants were then instructed to actively invert their foot as much as possible while the evaluator aligned the moving arm of the goniometer with the second metatarsal and ROM was recorded to the nearest degree [21]. This technique has shown moderate to high intra-rater reliability (r=0.83) and moderate correlation to a reference standard (3SPACE Fastrak electromagnetic tracking system; r=0.52-0.58) [21].

Inversion and Eversion MVIC. A handheld dynamometer (HHD; Baseline 12-0303 MMT, Fabrication Enterprise, Elmsford, NY) was used to assess ankle inversion and eversion MVIC. For inversion, participants lied on their side with the medial aspect of the testing leg facing upward. With the subject's foot in a neutral position the HHD was placed near the base of the first metatarsal head along the medial border of the foot. For eversion, participants switched their side-lying position so that the lateral aspect of the testing leg was facing upwards and the HHD was placed against the lateral border of the foot just below the fifth metatarsal head. For both tests participants were instructed to "make" a 3-5 second maximal isometric contraction effort against the HHD held by the evaluator [22–24]. HHD is considered a valid and reliable (r=0.88-0.95) tool for assessing ankle strength [22].

Figure-8 Hop Test. A 1-leg figure-8 hop test was used to assess stability and agility related to ankle function [24]. The figure-8 hop test was performed by having participants hop on one leg in a figure-8 pattern around two cones placed 5m apart from each other. Participants were instructed to hop as quickly as possible through the course [24]. Time to complete the course was recorded via a stopwatch. Docherty et al. found a small but significant correlation between the figure-8 hop test and functional ankle instability (r=0.31) and suggested that this may detect aspects of ankle instability directly related to the lateral structures of ankle [25].

Training Interventions

Following familiarization participants were randomly assigned to either the TRA or SUP training. In both conditions participants completed supervised training 3 days per week for 6 weeks, with each training session lasting approximately 10 minutes.

Traditional ankle training program. The TRA group performed 3 exercises each session including seated band resisted ankle inversion and eversion, standing band resisted leg abductions [24], and a single leg distance hopping series [26]. For the inversion and eversion exercise, one end of a resistance band (RB: Mini Bands, Perform Better, Providence, RI) was fixed around the leg of a training table while the opposite end of the RB was placed around the subject's foot about one quarter of the way down from the toes. The subject then stretched the RB to a point marked on the floor representing approximately an additional 70% of the RB's resting length, then assumed a modified long sitting position on the floor and used the heel as a fulcrum while inverting or everting the foot. Participants were instructed to only use the involved ankle and maintain a consistent pace of 3-5 seconds per rep [24]. Standing lateral leg raises were performed by having the participants wrap the RB around each ankle and then laterally raising one leg in a slow controlled manner against the resistance. Following the banded exercises, the participants performed a single leg distance hop series (SDHS) based on the protocol used by Lazarou et al. [26]. The series included 8 jumps (forward, backward, left, right, and all 4 diagonals) and was repeated once on each leg for one complete series. Throughout the 6-week intervention participants progressed by increasing the number of sets, band resistance, or decreasing rest between sets (Table 2).

Table 2. Traditional Ankle Training Program

	Seated band inversion and eversion, standing leg abduction		SDHS
	resistance band	sets x reps	sets
Week 1	Light	2x10	2
Week 2	Light	3x10	2
Week 3	Medium	2x10	3
Week 4	Medium	3x10	3
Week 5	Heavy	2x10	3*
Week 6	Heavy	3x10	3*

SDHS = single leg distance hop series. * = only 15 seconds rest between sets

Supination training program. The SUP group also performed 3 exercises each session consisting of standing lateral ankle rockers, supinated bodyweight squats, and supinated walking. To perform the lateral ankle rockers, participants stood with their feet about shoulder width apart and then shifted their weight laterally to one leg while rolling to the outside edge of that foot, achieving a supinated position, before switching directions to the opposite leg and foot. Following the lateral ankle rockers, participants performed body weight squats with their feet and ankles in a supinated position and roughly shoulder width apart. Finally, participants performed supinated walking by traveling 10 yards down-and-back while attempting to land on the outside edge of their feet with every step. The number of sets, distance traveled and/or rest between sets (rest between sets during weeks 5 and 6 was reduced to 15 seconds to mirror the TRA protocol) was progressed over the 6-week intervention (Table 3).

Table 3. Supination Ankle Training Program

	Rockers (sets x reps)	Supinated squats (sets x reps)	Dynamic supinated walks (yds)
Week 1	2x10	2x10	10
Week 2	2x10	2x10	10
Week 3	3x10	3x10	15
Week 4	3x10	3x10	15
Week 5	3x10*	3x10*	20
Week 6	3x10*	3x10*	20

* = only 15 seconds of rest

Statistical Analysis

Statistical analyses were performed using SPSS version 28.0 (SPSS Inc., Chicago, IL). Statistical significance was set *a priori* at $p < 0.05$. Descriptive statistics were calculated for all variables. Data was tested for normality using the Shapiro-

Wilk test. A 2 (group: TRA, SUP) x2 (time: Pre, Post) Repeated Measures ANOVA was used to assess differences in ankle inversion ROM, inversion and eversion average peak force, and figure-8 hop test time between groups before and after the 6-week training intervention. Bonferroni post hoc assessments were used to examine significant interaction and main effects for time, while independent t-tests were used to examine any significant main effects for group. Effect sizes were calculated using partial eta squared (h_p^2) (small = 0.01, medium = 0.06, & large = 0.14).

Results

Ankle Strength

There was no significant interaction ($F(2, 28)=0.83$, $p=0.776$) or main effect of group ($F(2, 28)=1.43$, $p=0.242$) for right ankle inversion strength (InvR) between the TRA (pre: 15.7 ± 2.2kg; post: 20.2 ± 3.0kg) and SUP training groups (pre: 16.2 ± 2.4kg; post: 21.1 ± 3.2kg). There was a significant main effect of time ($F(2, 28)=34.96$, $p<0.001$; $h_p^2=0.555$) showing an average improvement of 4.74 ± 4.29kg across groups. Similarly, there was no significant interaction ($F(2, 28)=0.32$, $p=0.579$) or main effect of group ($F(2, 28)=0.19$, $p=0.67$) for left ankle inversion strength (InvL) between the TRA (pre: 15.3 ± 2.4kg; post: 19.3 ± 3.4kg) and SUP groups (pre: 14.5 ± 2.2kg; post: 19.3 ± 3.8kg) however there was a main effect of time ($F(2, 28)=41.83$, $p<0.001$; $h_p^2=0.599$) showing an average improvement of 4.43 ± 3.68kg pre to post.

There was no significant interaction ($F(2, 28)=0.52$, $p=0.477$) between groups for right ankle eversion strength (EvR). There was a significant main effect of group ($F(2, 28)=6.61$, $p=0.016$; $h_p^2=0.191$). Post hoc analysis showed that SUP EvR strength was significantly greater than TRA at pre-test ($p=0.026$; 18.49 ± 3.74 vs 15.49 ± 3.20kg, respectively) but no difference between groups at post-test ($p=0.083$; 23.2 ± 2.9 vs 21.2 ± 2.1kg). Additionally, there was a significant main effect of time ($F(2, 28)=55.32$, $p<0.001$; $h_p^2=0.664$) showing an average improvement of 5.17 ± 3.79kg for all participants. Similarly, there was no significant interaction ($F(2, 28)=0.04$, $p=0.848$) for left ankle eversion strength (EvL), however there was a significant main effect of group ($F(2, 28)=11.63$, $p=0.002$; $h_p^2=0.294$) with post hoc analysis identifying significant differences between SUP and TRA at pre- ($p=0.005$; 19.10 ± 3.35 vs. 15.68 ± 2.65kg) and post-test ($p=0.005$; 23.62 ± 3.01 vs. 20.39 ± 2.71kg). Again, there was a significant main effect of time ($F(2, 28)=95.17$, $p<0.001$; $h_p^2=0.773$) indicating an overall average improvement pre to post of 4.61 ± 2.54kg (Figure 1).

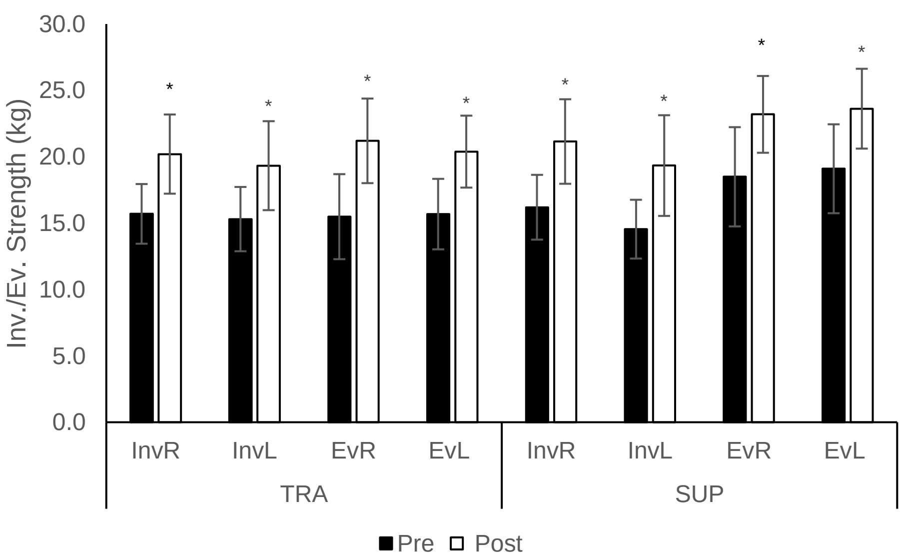

Figure 1. Ankle inversion and eversion strength (kg) pre- and post-test comparison between TRA (traditional ankle training) and SUP (supination style ankle training) groups. InvR = right ankle inversion; InvL = left ankle inversion; EvR = right ankle eversion; EvL = left ankle inversion; * = post-test significantly greater than pre-test ($p<0.001$).

Inversion ROM

There was no significant interaction or main effect of group for right ankle inversion ROM (romR; $F(2, 28)=0.23$, $p=0.635$ & $F(2, 28)=1.83$, $p=0.061$, respectively; TRA pre 34.15 ± 5.32°, post 38.60 ± 4.70°; SUP pre 36.26 ± 5.15°, post 41.21 ± 4.66°). There was a significant main effect for time (F(2, 28)=82.83, $p<0.001$; $h_p^2=0.747$) showing an overall average improvement from pre to post of 4.72 ± 2.79°. There was no significant interaction for left ankle inversion ROM (romL; F(2, 28)=0.01, $p=0.927$), however, there was a significant main effect of group (F(2, 28)=7.25, $p=0.012$; $h_p^2=0.206$) with post hoc analysis indicating a significant difference between SUP and TRA at post-test ($p=0.005$; 41.50 ± 3.56° vs 37.40 ± 3.86°). Additionally, there was a significant main effect of time (F(2, 28)=27.51, $p<0.001$; $h_p^2=0.496$) indicating an overall average improvement of 4.64 ± 4.76° from pre to post (Figure 2).

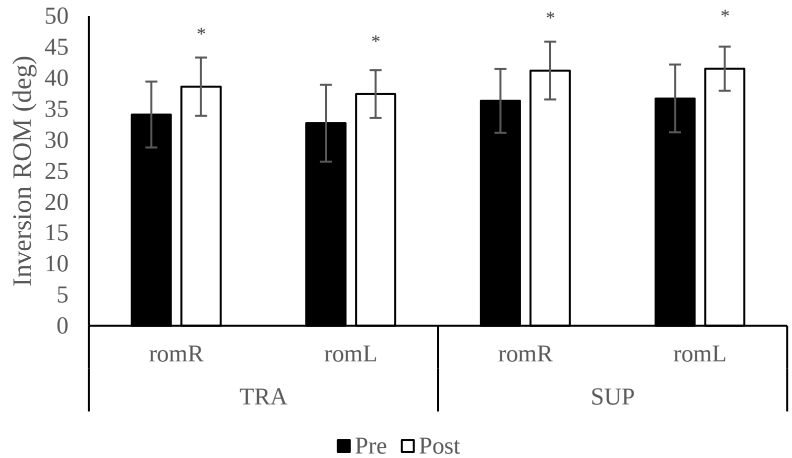

Figure 2. Ankle inversion range of motion (ROM) pre- and post-test comparison between TRA (traditional ankle training) and SUP (supination style ankle training) groups. romR = right ankle inversion ROM; romL = left ankle inversion ROM; * = post-test significantly greater than pre-test ($p<0.001$).

Figure-8 Hop Test

There was no significant interaction or main effect of group for figure-8 right trial (fig8R; F(2, 28)=0.37, $p=0.546$ & F(2, 28)=0.23, $p=0.634$, respectively; TRA pre 4.88 ± 0.59, post 4.45 ± 0.61sec; SUP pre 4.74 ± 0.54, post 4.37 ± 0.66sec) and figure-8 left trial (fig8L; F(2, 28)=0.36, $p=0.553$ & F(2, 28)=0.49, $p=0.488$, respectively; TRA pre 4.87 ± 0.62, post 4.47 ± 0.56sec; SUP pre 4.67 ± 0.60, post 4.35 ± 0.63sec). There was a significant main effect of time for fig8R (F(2, 28)=67.72, $p<0.001$, $h_p^2=0.707$) and fig8L (F(2, 28)=57.36, $p<0.001$, $h_p^2=0.672$) showing an overall average improvement of -0.40 ± 0.26sec and -0.37 ± 0.26sec, respectively (Figure 3).

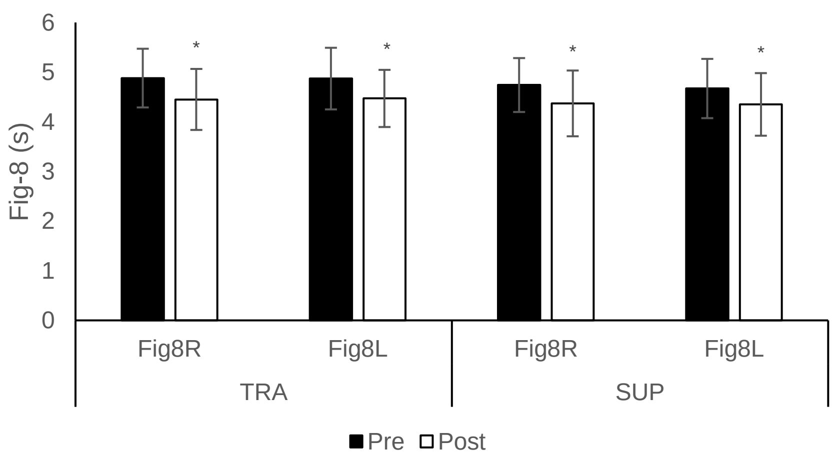

Figure 3. Single leg Figure-8 hop test (seconds) pre- and post-test comparison between TRA (traditional ankle training) and SUP (supination style ankle training) groups. Fig8R = right leg figure-8; Fig8L = left leg figure-8; * = post-test significantly lower than pre-test ($p<0.001$).

Discussion

The purpose of this study was to compare the effects of a novel supination-style ankle strengthening protocol to a traditional protocol on common LAS indices in NCAA Division III collegiate football players. Over the course of 6 weeks of training 3 times per week (18 sessions) both protocols resulted in significantly greater inversion and eversion strength, greater inversion ROM, and improved performance in the Figure-8 hop test. Supination-style training resulted in significantly greater left ankle inversion ROM at post-test than the traditional protocol, otherwise there were no significant differences between groups for each variable. These results indicate that this novel supination-style of training is comparable to traditional training protocols in terms of effectiveness for improving ankle function related to LAS.

Inversion and eversion are frontal plane motions with excessive inversion being associated with LAS. Inversion and eversion occur at the anatomical (posterior) subtalar joint in an open kinetic chain scenario (i.e., non-weight bearing) [27]. However, in closed kinetic chain (CKC) scenarios (i.e., weight bearing with foot on ground and calcaneus fixed) both the posterior and anterior subtalar joint, and therefore its connection to the navicular and cuboid bones, contribute to inversion and eversion [28]. As such calcaneal inversion becomes CKC supination, which includes a combination of plantar flexion, inversion, adduction and external rotation of the tibia and medial foot column [9,28]. In CKC, calcaneal eversion becomes pronation and includes dorsiflexion, eversion, abduction and internal rotation of the tibia and medial foot column [8]. With this understanding it becomes clear that in CKC (the position of LAS injuries) the pathomechanics of LAS involve a multi-planar supination motion of the foot and ankle and not strictly subtalar inversion alone [8]. This provided the inspiration and rationale for the development of this study's CKC supination-style training program for comparison to traditional ankle strengthening and injury prevention protocols.

It has been theorized that LAS occurs via excessive supination in roughly 40 milliseconds at a speeds of 700°/sec or greater [8,9]. Ankle ROM may be associated with LAS, specifically an excessive anterior draw and talar tilt [10,11], however evidence regarding this is mixed [12]. Theoretically, in a CKC scenario, greater available inversion ROM would decrease the incidence of experiencing "excessive" supination. In the present study we showed that both a traditional approach and the novel supination-style approach improved inversion ROM (roughly 4.5 to 5 degrees; see supplemental materials Table S1). Increased inversion ROM following the supination style training makes sense as the exercises performed in this protocol involved controlled eccentric ankle inversion. Interestingly, the traditional training method also improved ROM. This may be due to the seated resistance band inversion and eversion exercise, where during the eversion component participants resisted an inversion motion eccentrically and followed with a concentric eversion contraction.

Although controversial, both reduced hip and ankle strength may be independent predictors of LAS [13]. Specifically, higher eversion to inversion strength ratios has been associated with greater incidence of LAS [14]. Interestingly in the present study both protocols increased eversion and inversion strength (approximately 4-6 kg; see supplemental Table S1). This finding is not surprising for the traditional training group in which resistance band eversion and inversion exercises were provided but is slightly harder to explain for the supination-style group, specifically regarding the increased inversion strength. It is possible inversion strength may have improved due to the lateral ankle rocker exercise in which while one ankle supinated the opposite ankle pronated, eccentrically challenging muscles involved in inversion. Another interesting finding with respect to strength and neuromuscular control was the improvement in the Figure-8 hop test seen in both groups. Again, this was not surprising for the traditional group given that participants performed the single leg distance hop series which is similar to the Figure-8 hop test. The improvement in the supination-style group is again hard to explain. However, it highlights the possibility of this style of training's ability to improve dynamic neuromuscular control.

The incidence of ankle injuries including LAS are among the highest reported [4]. In particular, LAS tends to result in a negative feedback loop in which the injury results in a more vulnerable ankle joint due to altered biomechanics and neural control, and therefore increases the chance of future injury [15,29]. Unfortunately, up to 70% of individuals with LAS experience re-injury [15,30], highlighting the importance of preventing the first LAS incident. Most LAS injuries involve an altered transition of bodyweight absorption as the individual approaches the ankle rocker phase suggesting altered biomechanical and neuromuscular control [8]. Research has shown exercise interventions to be promising for preventing ankle injuries, with those that specifically target proprioception and neuromuscular control appearing to be the most effective [15].

Although this study is strengthened by using a randomized parallel groups design with supervised training and simple assessments of the ankle that have shown correlations to LAS, there are several limitations that should be considered. First, it would be difficult to generalize these findings to female athletes and athletes who play other sports at different levels (high school vs. professional). As such, future research directed at more diverse populations is needed. Additionally, as noted earlier, the evidence linking range of motion and lateral ankle strength to higher rates of LAS is mixed. Conceptually, increasing available ROM and strength using training that more closely mimics the nature of LAS should reduce injury rates, and warrants future research. Finally, the increases in inversion and eversion strength and Figure-8 hop performance must be considered cautiously since all participants remained on their regular strength and conditioning program and the degree to which this may have influenced results cannot be ascertained. However, it should be noted that the strength and conditioning program included mostly bilateral traditional strength and power exercises (excluding plyometric or neuromuscular training modalities).

Conclusions

In the present study, closed kinetic chain supination-style training improved several indices related to LAS, including ankle inversion and eversion strength, ankle inversion ROM, and dynamic stability assessed via the Figure-8 hop test in NCAA Division III football players. The magnitude of improvements across each of these variables were similar to the improvements seen with more commonly used ankle rehabilitation and strengthening exercises. Although both training groups required minimal equipment and space, a key difference was the upright, CKC nature of the supination-style training in which the movements for each exercise performed mirrored the foot and ankle motion often seen in LAS. The improvements in ankle ROM, strength and dynamic neuromuscular control seen in the supination-style training as well as its unique resemblance to motion of LAS warrants future investigations as a preventative and/or rehabilitative strategy.

Acknowledgements

Funding for this research was provided internally by the Grove City College Department of Exercise Science. The authors wish to thank the participants for their vital contribution to this study.

References

1. Halabchi F, Hassabi M. Acute ankle sprain in athletes: Clinical aspects and algorithmic approach. *World J Orthop*. 2020;11(12):534-558. doi:10.5312/wjo.v11.i12.534
2. Polzer H, Kanz KG, Prall WC, et al. Diagnosis and treatment of acute ankle injuries: development of an evidence-based algorithm. *Orthop Rev*. 2012;4(1):e5. doi:10.4081/or.2012.e5
3. Doherty C, Delahunt E, Caulfield B, Hertel J, Ryan J, Bleakley C. The incidence and prevalence of ankle sprain injury: a systematic review and meta-analysis of prospective epidemiological studies. *Sports Med Auckl NZ*. 2014;44(1):123-140. doi:10.1007/s40279-013-0102-5
4. Kerr ZY, Nedimyer AK, Simon JE, Kossman MK, Corbett RO, Chandran A. The epidemiology of ankle sprains in United States high school sports, 2011/12-2018/19 academic years. *J Athl Train*. Published online March 10, 2022. doi:10.4085/1062-6050-0664.21
5. Chandran A, Morris SN, Powell JR, Boltz AJ, Robison HJ, Collins CL. Epidemiology of Injuries in National Collegiate Athletic Association Men's Football: 2014–2015 Through 2018–2019. *J Athl Train*. 2021;56(7):643-650. doi:10.4085/1062-6050-447-20
6. Kristianslund E, Bahr R, Krosshaug T. Kinematics and kinetics of an accidental lateral ankle sprain. *J Biomech*. 2011;44(14):2576-2578. doi:10.1016/j.jbiomech.2011.07.014
7. Gehring D, Wissler S, Mornieux G, Gollhofer A. How to sprain your ankle – a biomechanical case report of an inversion trauma. *J Biomech*. 2013;46(1):175-178. doi:10.1016/j.jbiomech.2012.09.016
8. Medina McKeon JM, Hoch MC. The Ankle-Joint Complex: A Kinesiologic Approach to Lateral Ankle Sprains. *J Athl Train*. 2019;54(6):589-602. doi:10.4085/1062-6050-472-17
9. Fong DTP, Ha SCW, Mok KM, Chan CWL, Chan KM. Kinematics Analysis of Ankle Inversion Ligamentous Sprain Injuries in Sports: Five Cases From Televised Tennis Competitions. *Am J Sports Med*. 2012;40(11):2627-2632. doi:10.1177/0363546512458259
10. Glick JM, Gordon RB, Nishimoto D. The prevention and treatment of ankle injuries. *Am J Sports Med*. 1976;4(4):136-141. doi:10.1177/036354657600400402
11. Chomiak J, Junge A, Peterson L, Dvorak J. Severe Injuries in Football Players. *Am J Sports Med*. 2000;28(5_suppl):58-68. doi:10.1177/28.suppl_5.s-58
12. Beynnon BD, Murphy DF, Alosa DM. Predictive Factors for Lateral Ankle Sprains: A Literature Review. *J Athl Train*. 2002;37(4):376-380.

13. Delahunt E, Remus A. Risk Factors for Lateral Ankle Sprains and Chronic Ankle Instability. *J Athl Train*. 2019;54(6):611-616. doi:10.4085/1062-6050-44-18
14. Beynnon BD, Renström PA, Alosa DM, Baumhauer JF, Vacek PM. Ankle ligament injury risk factors: a prospective study of college athletes. *J Orthop Res*. 2001;19(2):213-220. doi:10.1016/S0736-0266(00)90004-4
15. Kaminski TW, Needle AR, Delahunt E. Prevention of Lateral Ankle Sprains. *J Athl Train*. 2019;54(6):650-661. doi:10.4085/1062-6050-487-17
16. Verhagen E a. LM, Bay K. Optimising ankle sprain prevention: a critical review and practical appraisal of the literature. *Br J Sports Med*. 2010;44(15):1082-1088. doi:10.1136/bjsm.2010.076406
17. McKeon PO, Mattacola CG. Interventions for the prevention of first time and recurrent ankle sprains. *Clin Sports Med*. 2008;27(3):371-382, viii. doi:10.1016/j.csm.2008.02.004
18. Schiftan GS, Ross LA, Hahne AJ. The effectiveness of proprioceptive training in preventing ankle sprains in sporting populations: a systematic review and meta-analysis. *J Sci Med Sport*. 2015;18(3):238-244. doi:10.1016/j.jsams.2014.04.005
19. Hübscher M, Zech A, Pfeifer K, Hänsel F, Vogt L, Banzer W. Neuromuscular training for sports injury prevention: a systematic review. *Med Sci Sports Exerc*. 2010;42(3):413-421. doi:10.1249/MSS.0b013e3181b88d37
20. Gutierrez GM, Kaminski TW, Douex AT. Neuromuscular control and ankle instability. *PM R*. 2009;1(4):359-365. doi:10.1016/j.pmrj.2009.01.013
21. Menadue C, Raymond J, Kilbreath SL, Refshauge KM, Adams R. Reliability of two goniometric methods of measuring active inversion and eversion range of motion at the ankle. *BMC Musculoskelet Disord*. 2006;7(1):60. doi:10.1186/1471-2474-7-60
22. Burns J, Redmond A, Ouvrier R, Crosbie J. Quantification of muscle strength and imbalance in neurogenic pes cavus, compared to health controls, using hand-held dynamometry. *Foot Ankle Int*. 2005;26(7):540-544. doi:10.1177/107110070502600708
23. Carroll M, Joyce W, Brenton-Rule A, Dalbeth N, Rome K. Assessment of foot and ankle muscle strength using hand held dynamometry in patients with established rheumatoid arthritis. *J Foot Ankle Res*. 2013;6:10. doi:10.1186/1757-1146-6-10
24. Hall EA, Docherty CL, Simon J, Kingma JJ, Klossner JC. Strength-training protocols to improve deficits in participants with chronic ankle instability: a randomized controlled trial. *J Athl Train*. 2015;50(1):36-44. doi:10.4085/1062-6050-49.3.71
25. Docherty CL, Arnold BL, Gansneder BM, Hurwitz S, Gieck J. Functional-Performance Deficits in Volunteers With Functional Ankle Instability. *J Athl Train*. 2005;40(1):30.
26. Lazarou L, Kofotolis N, Pafis G, Kellis E. Effects of two proprioceptive training programs on ankle range of motion, pain, functional and balance performance in individuals with ankle sprain. *J Back Musculoskelet Rehabil*. 2018;31(3):437-446. doi:10.3233/BMR-170836
27. Krähenbühl N, Horn-Lang T, Hintermann B, Knupp M. The subtalar joint: A complex mechanism. *EFORT Open Rev*. 2017;2(7):309-316. doi:10.1302/2058-5241.2.160050
28. Usuelli FG, Mason L, Grassi M, Maccario C, Ballal M, Molloy A. Lateral ankle and hindfoot instability: A new clinical based classification. *Foot Ankle Surg*. 2014;20(4):231-236. doi:10.1016/j.fas.2014.05.003
29. Hertel J. Sensorimotor Deficits with Ankle Sprains and Chronic Ankle Instability. *Clin Sports Med*. 2008;27(3):353-370. doi:10.1016/j.csm.2008.03.006
30. Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. *Br J Sports Med*. 2005;39(3):e14-e14. doi:10.1136/bjsm.2004.011676