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An Off-Season Brace-Free Neuromuscular Ankle Training Program Among Brace-Reliant and Nonbrace-Reliant Division II Female Athletes

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Background: Neuromuscular training (NMT) has been shown to be effective in preventing recurrent ankle injuries. However, the NMT effect during the off-season in athletes who wear and those who do not wear an ankle brace during their sport season remains undetermined.
Purpose: The purpose of this study was to determine the effect of an off-season brace-free neuromuscular ankle training program on ankle functional ability among female athletes who wore and those who did not wear an ankle brace during the sport season.
Study Design: This study included a pre- and posttest 2-group cohort.
Methods: In this study, division II female athletes (n = 31) participated: 15 wore an ankle brace during their competitive sports season (brace-reliant), whereas the remaining 16 had never worn an ankle brace (brace-naïve). Subjects completed a 4-phase, 6-week neuromuscular ankle training program incorporated into an off-season conditioning program. Subjects were provided instruction and were asked to complete the 10-minute progressive program 3 times per week for 6 weeks. Subjective and objective measures of ankle functional ability were collected before and after the 6-week intervention. Subjective measures involved the subjects completing the Foot and Ankle Ability Measures, including a global rating of condition and the TAMPA Scale for Kinesiophobia. Objective measures of ankle functional ability included single-leg hop distance and single-leg balance with eyes closed duration.

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Results: The brace-reliant group experienced significant improvement ($P < .05$) in 3 of the 4 objective measures of functional ankle stability and this improvement was greater than that experienced by the brace-naïve group on the single-leg hop distance bilaterally.
Conclusions: A brace-free NMT program during the off-season improved objective ankle functional ability among female athletes who routinely wear ankle braces during competition. Athletes who wear ankle braces may exhibit neuromuscular and functional performance deficits, and they may have a greater potential for improving these measures compared with those who do not wear ankle brace.

Keywords: Ankle sprain; female athlete; soccer; volleyball; proprioception; prevention

Key Point: An off-season neuromuscular training program can improve functional deficits in soccer athletes who routinely wear ankle braces.

Ankle sprains are one of the most common sports-related injuries, accounting for 10%–30% of all sport-related injuries, and with >23,000 ankle sprains occurring daily in the USA[1]. Sports-related injuries involving the ankle joint are second only to those involving the knee joint in a review of injuries among 33 of 43 global sporting activities.[1] Several authors have reported that the ankle is the most frequently injured joint among soccer players.[1–6] Similarly, ankle sprains account for about half of all acute volleyball injuries at rates comparable or even higher than those of soccer.[1,7]

The National Collegiate Athletic Association conducted epidemiology surveillance studies of college-going women's soccer and volleyball players from 1988 to 2003. Ankle sprains were one of the most frequently occurring injuries sustained during both games and during practices for both games. Among soccer players, it has been reported that between 15% and 18% of all injuries involved ankle sprains.[8] Further, ~45% of all injuries reported in college-going female volleyball players comprised ankle sprains.[9] Athlete who have experienced an ankle sprain are more susceptible to recurring ankle injuries.[10,11] Both the soccer and volleyball National Collegiate Athletic Association surveillance studies recommend efforts to prevent first-time ankle sprains and reduce the risk of recurring ankle sprains through neuromuscular training (NMT) programs.[8,9] These recommendations have been recently reinforced in a 2016 Consensus Statement of the International Ankle Consortium[12] along with the recognition that the direct and indirect financial and societal costs for treating ankle sprains and their sequelae are high. The Consensus Statement of the International Ankle Consortium also emphasized the need for future research to examine and determine optimal timelines of decline in physical activity, to examine potential associations of lateral ankle sprains with comorbidity, and to improve interventions including prevention programs (timing, dosage, and intensity) to alleviate declines in physical activity.

Ankle sprains have been shown to result in proprioceptive deficits at the ankle, which indicates the need to develop interventions that reduce the incidence and severity of future ankle injuries while maintaining or improving ankle functional ability.[13] One of the most frequently used interventions to increase ankle stability is bracing. Numerous studies have indicated that ankle bracing which includes taping or wearing an ankle brace can improve ankle stability and decrease recurrent ankle sprains.[14,15] While decreasing instability and recurrent injuries, ankle bracing may also limit inversion and eversion of the ankle, and some athletes associate this decrease in range of motion with decreased sport performance.[16] This limited inversion/

eversion range of motion that results from ankle bracing is likely accompanied by declining functional capacity (strength and/or proprioception) of the ankle inversion/eversion ligaments to resist and respond to normal mechanical stresses.[17] Thus, sustained ankle bracing alone may have deleterious effects on the musculoskeletal structures at the ankle joint, which may become evident when the individual does not wear the ankle brace. Thus, NMT programs and strength training are recommended to increase ankle stability.[18]

Various NMT programs have been developed to increase ankle stability and reduce future ankle sprains.[2,6,13,19] These NMT programs are sometimes preferred over bracing because they do not affect ankle mobility, are relatively inexpensive, and require minimal equipment and minimal time to implement. In a comprehensive review of 9 ankle NMT intervention studies, 7 reported positive effects with the primary outcome related to a reduced injury rate.[2,5–7,11] The results of these studies indicate that both ankle bracing and ankle NMT can improve ankle stability and reduce ankle sprains. What has not been adequately studied, however, is the effect of neuromuscular ankle training programs on ankle functional ability among athletes who wear and those who do not wear ankle brace during competition. It is hypothesized that athletes who wear an ankle brace during the sports season may have greater capacity to respond positively to the effects of a neuromuscular ankle training program while not wearing the ankle brace during off-seasons. Therefore, the purpose of this study is to determine the effect of an off-season brace-free neuromuscular ankle training program on ankle functional ability among female athletes who wore and those who did not wear an ankle brace during the sport season.

METHODS

This study was approved by Bellar-mine University Institutional Review (IRB #1113-3). It was conducted during the off-season at a division II university among female soccer and volleyball players. Data were collected before and after a 6-week neuromuscular ankle training program incorporated as a component of an off-season conditioning program. Approximately half of athletes in the combined sample wore an ankle brace during their sports season. This resulted in the following 2-group pretest–posttest design: female athletes wore an ankle brace during their sports season (brace-reliant) and athletes who did not wear (brace-naïve) an ankle brace during their sports season.

Participants

Participants were recruited from division II women's soccer and volleyball teams at a single university through communication with the head coaches, team athletic trainer, and strength and conditioning coach. Interested individuals were instructed to call a member of the research team to discuss the protocol and confirm inclusion/exclusion criteria. These criteria included female gender, participation in the previous sports season, ability to participate in the off-season conditioning program 3 times per week, no lower extremity surgery in the past year, and free of any lower extremity injury within the past 3 months. Before data collection, participants provided informed consent by signing an institution-approved consent form (Bellarmine University IRB #1113-3).

Neuromuscular Ankle Training Program

The program was designed using components adapted and/or modified from previously published reports on ankle sprain prevention and proprioception programs.[3,5–7] The program was intentionally designed to be inexpensive, to require minimal time burden, to be progressive in intensity, and to be incorporated into a regular off-season conditioning program (see Appendixes A and B). Subjects were asked to complete their sportsspecific training program 3 times per week for 6 weeks. The training programs involved 10 minutes of performing sport-specific maneuvers while standing on increasingly unstable surfaces over the 6-week program. Examples of sport-specific activities for soccer included single-leg standing while passing the soccer ball with the free foot in vertical and horizontal directions. Volleyball sport-specific activities included single-leg standing while volleying a ball with a teammate. During the first week of the program, the training was completed while standing on a level surface such as a court or field surface; during the second week of the program, subjects performed activities on foam stability trainers and balance boards (Performance Health, Akron, OH); during the third and fourth weeks of the program, subjects performed activities on a less dense (more challenging) foam stability trainer; and during the fifth and sixth weeks, the exercises were advanced in difficulty by being performed on wobble boards.

Outcome Measures

Ankle functional ability was measured subjectively and objectively before and immediately after the 6-week training program. Subjective ankle functional ability was assessed with the Foot and Ankle Ability Measures (FAAM)-Sports, a global rating of function, and the TAMPA Scale of Kinesiophobia. The FAAM-Sports consists of 8 items that assess perceived foot and ankle functioning while engaged in sports activities on a 5-point Likert scale, with higher scores indicating higher ankle functional ability. The range of scores on the FAAM-Sports is 0-100 with a minimal clinically important difference of 9 points for this instrument.[20,21] The global rating of condition (GROC) was assessed by a single assessment numerical rating by answering the question: "On a scale of 0–100, how would you rate the overall function of your ankle?" The global rating of function has been reported by previous authors as having good correlation with the overall comprehensive scoring in other region-specific outcome measures used for the shoulder, knee, and ankle.[22–24] Finally, subjective ankle functional ability operationalized as fear of re-injury and fear of pain was assessed by the subject completing the TAMPA Scale of Kinesiophobia. This 11-item instrument scores range from 11 to 44 points, with lower scores indicating lower levels of kinesiophobia.[25]

Two objective measures of ankle functional ability were measured bilaterally. The duration of time the individual was able to maintain a single-leg-stand position with eyes closed (SLSEC)[26] and the single-leg hop (SLH) for a distance. For the SLSEC, subjects were instructed to place their hands on their hips and elevate the nontest leg, close their eyes and maintain this position for as long as possible. The longest duration the subject was able to maintain this position over 3 trials was considered their single-leg-stand score for each leg. To assess SLH subjects were instructed to stand on 1 leg and to position their toes on a mark on the floor. The subject was then asked to hop forward as far as possible and to land on the same leg. The subject was allowed to swing his arms freely as she jumped. The distance, in centimeters, was measured from the toe in the starting position to the heel where the subject landed. A hop was only regarded as successful if the subject was able to keep their foot in place while balancing on 1 leg (i.e. no extra hops were allowed) until an investigator had marked where the subject had landed. The test was performed until 3 successful hops were obtained for each leg and the furthest distance for each trial was considered the subject's SLH distance.[27]

Analysis to address the purpose consisted of calculating repeated-measures ANOVA equations, with each of the subjective and objective measures being the dependent variables, the independent variables of the test (pretest vs posttest), and the ankle brace history (brace-reliant vs

Table 1. Sample descriptors (n = 31)

	Mean	SD
Age	19.61	1.09
Height (inches)	67.03	3.29
Weight (lbs.)	140.29	15.49
BMI	21.93	1.73
Years in College	2.03	.88

Table 2. Use of ankle brace by sport

Sport	Brace-Naïve	Brace-Reliant
Soccer	14 (66.7%)	7 (33.3%)
Volleyball	2 (20%)	8 (80%)
Total	16 (51.6%)	15 (48.4%)

Note: Chi-square = 5.91 (df = 1) $P < .01$.

brace-naïve), as well as the interaction of test and ankle brace history. Significant main or interaction effects ($P < .05$) were explored further by calculating Tukey post hoc comparisons to determine differences between means.

RESULTS

Tables 1 and 2 present the characteristics of the sample. The physical characteristics of the sample, particularly their body mass index, indicated they were physically fit. Table 2 indicates that a higher proportion ($P < .05$) of volleyball players (80%) used an ankle brace during the sport season compared with that of soccer players (33%). This difference was attributable to a general consensus report from the soccer players indicating that an ankle brace inhibits performance.

Table 3 presents changes in the subjective and objective measures of ankle functional ability at pretest and posttest among the brace-reliant (n = 15) and brace-naïve (n = 16) members of the sample. The groups were neither different at any data collection point nor did either group exhibit a change on any of the subjective measures of ankle functional ability. The objective measures of ankle functional ability in the brace-naïve group did not change because of the 6-week training program. The brace-reliant group showed significant gains in the SLSEC on the left and the SLH bilaterally. These gains observed in the SLH among the brace-reliant group resulted in significantly greater performance on these measures compared with the those observed in the SLH among the brace-naïve group at posttest (9%–13% difference between the groups). The brace-reliant also exhibited a nonsignificant trend toward improving their performance in the SLSEC on the right (30% improvement), whereas the brace-naïve group did not exhibit this trend because of the neuromuscular ankle training program (4% gain).

DISCUSSION

The findings support the study hypothesis and indicate that the brace-reliant group's objective measures of ankle functional ability responded positively to the neuromuscular ankle training program, whereas the brace-naïve group's objective measures of ankle functional ability did not change on any of these measures. Further, the findings indicate that no change was observed in both groups regarding their subjective measures of ankle functional ability because of the program. The finding that the training program improved the objective measures of ankle functional ability is consistent with that of previous investigators who reported similar benefits of the ankle training program.[2,5,6,13,19] What was unexpected was that benefits of the neuromuscular ankle training program were only observed among the brace-reliant group. Evidence suggests that ankle bracing decreases the incidence of first-time and subsequent ankle injuries.[28,29] The current clinical recommendations following an ankle sprain often involve mechanical bracing of the ankle and NMT.[5]

Table 3. Effect of a 6-week ankle training program on perceptions and functioning among female athletes who wear and do not wear an ankle brace during the sport season

Variable	Brace-Reliant (n = 15)	Brace-Reliant (n = 15)	Brace-Naïve (n = 16)	Brace-Naïve (n = 16)
	Pretest	Posttest	Pretest	Posttest
FAAM	89.53 ± 3.54	91.53 ± 2.72	93.72 ± 3.43	94.75 ± 2.64
GROC	94.07 ± 3.48	96.53 ± 1.95	89.63 ± 3.37	94.38 ± 1.89
TAMPA	34.73 ± 1.35	34.40 ± 1.41	31.69 ± 1.31	33.44 ± 1.37
Single-Leg Stand Eyes Closed Right (s)	16.20 ± 3.03	21.07 ± 3.01	19.59 ± 2.93	20.31 ± 2.91
Single-Leg Stand Eyes Closed Left (s)	15.71 ± 2.99	19.73 ± 2.55	19.01 ± 2.89	23.38 ± 2.47
Single-Leg Hop Right (cm)	60.68 ± 1.38	67.30 ± 1.80*	58.03 ± 1.33	59.66 ± 1.74
Single-Leg Hop Left (cm)	62.13 ± 1.53	66.77 ± 1.64*	59.05 ± 1.48	61.31 ± 1.59

Note: Shading indicates a significant change within the group between pretest to posttest; *indicates a significant difference between the groups at pretest or posttest Abbreviation: GROC, Global Rating of Condition Scale.

Recent evidence supports the view that ankle bracing is superior to NMT in reducing the incidence, but not the self-reported severity, of recurrent ankle sprains.[30]

The mechanisms by which ankle NMT and ankle bracing reduce recurrent ankle sprains are believed to be different. Bracing the ankle and external support mechanism is reported to have effects that align the ankle joint, decrease angular velocities, and limit the range of motion (eversion/inversion) in the frontal plane.[31,32] Ankle NMT interventions appear to be effective through a different mechanism by increasing neuromuscular control, improving proprioception and balance, increasing muscle activity, and supporting ligamentous structures.[33–35] Feger et al.[17] reported that ankle bracing significantly reduces muscle activity in the lateral gastrocnemius and the peroneus longus among individuals who have experienced recurrent ankle sprains. These authors concluded that the beneficial effects of ankle bracing are likely because of mechanical restraint and not improvements in muscle recruitment. In a review of NMT for chronic ankle instability, Lin et al.[19] indicated that the use of ankle bracing may also lead to adverse events by limiting the range of motion and muscle activation.

These previous studies and reviews may explain the current findings that only the brace-reliant group improved their objective measures of ankle functional ability because of the off-season ankle NMT program. Subjects who wore an ankle brace during their sport season may have presented at the off-season training program with a greater potential to improve their neuromuscular control, proprioception, and balance as assessed by the SLSEC and the SLH. That is, routinely wearing an ankle brace during the sports season may have limited the training response of the structures involved in the objective assessments of ankle functional ability assessed in this study. Thus, the findings of this study indicate that division II female athletes who wear an ankle brace during their sports season, or are as defined in this study as brace-reliant, may indeed have diminished ankle neuromuscular control, proprioception, balance, and lower leg muscle strength compared to their peers who did not wear an ankle brace during their sport season. If this is the case, then female athletes who wear an ankle brace during their sports season may require continued use of an ankle brace during their training season to prevent recurrence. However, these same athletes may also benefit from a highly predictable and controlled ankle NMT program while not wearing an ankle brace, both during their sports season and into the off-season to reduce their functional deficits as identified in this study. This approach may minimize ankle sprains during their competitive season through the use of bracing and reduce exposure of the ankle to inversion and eversion mechanical stresses. Although the goal is not necessarily to reduce dependence or reliance of the brace as a prophylactic measure, a brace-free ankle NMT during both in-season and during off-season may enhance the mechanisms that contribute to ankle functional ability including neuromuscular control, proprioception and balance as assessed by the SLSEC and the SLH.

The findings of this study and clinical recommendations must be interpreted cautiously because of a number of threats to the validity. First, the compliance rates with the off-season training program varied, with 87% of soccer players and 30% of the volleyball players, respectively, reporting completing the ankle NMT program at least 3 times per week. Second, neither group reported any changes in the subjective self-report measures of ankle functional ability because of the program. This finding may be attributable to the subjective measures being insensitive to the intervention or the sample exhibiting a ceiling effect in the measures, as they were highly trained and were not experiencing any ankle injury or dysfunction at the time of the study. Another limitation beyond the scope of the current study involved making determinations or recommendations about the quality, performance, or preference of types of braces worn, which were neither controlled for nor evaluated. Because the current study did not involve true randomization, the results reported are based purely on the observational findings of subjects who wore braces, and those who did not, as a personal preference, limiting the ability to determine true cause and effect.

Future studies in this area can advance the science by addressing these limitations and incorporating a more rigorous design. The assumption made in the current study was that athletes who wear braces (brace-reliant) may become dependent on the mechanical support provided by the brace and less on neuromuscular mechanisms which are impaired following injury. This is especially important following a recent ankle injury, or history of recurrent sprains, where additional external, mechanical support provided by a brace is needed. However, although this contention has not been fully validated by the current study design, an ongoing assessment of neuromuscular function or performance is needed in subjects who wear braces and those who do not. The different preventive mechanisms of bracing and NMT, while not fully understood, when used independently, have both been linked to an ~50% reduction in ankle sprain recurrence risk.[36] It is likely that optimal preventive measures will be observed when bracing and NMT programs are used in combination.[36] Future studies may wish to examine differences in neuromuscular control, proprioception, balance, and lower leg muscle strength among female athletes who wear and do not wear an ankle brace before, during, and following their sport season. The long-term effects of wearing an ankle brace also need to be evaluated on the functional ability of the ankle when not wearing the brace. If this program were to be repeated in the future on a similar sample, the addition of higher-level agility activities is recommended, such as the crossover hop test and the 6-meter hop test, or possibly the composite of a battery of tests such as those described by Caffrey et al.,[37] or recently popularized and standardized tests such as the functional movement screen[38,39] and the Y-balance test.[40] These assessments may be more sensitive to changes in objective ankle or lower extremity functional ability resulting from the ankle NMT program.

CONCLUSION

The off-season brace-free neuromuscular ankle training program significantly improved objective measures of ankle functional ability among female athletes who wore ankle braces during their sport season. This finding may indicate that female athletes who wear an ankle brace during their competitive season have a greater potential to improve neuromuscular control, proprioception, and balance after a brace-free off-season training program than those who do not wear an ankle brace. Wearing ankle braces to prevent or reduce the risk of an initial or recurrent injury is an important and desirable outcome for athletes who participate in sports with high risk of ankle injury. However, brace-reliant athletes should also be encouraged to continue NMT programs in a safe, controlled and predictable environment without their braces to reduce neuromuscular and functional performance deficits that may be a result of wearing such braces.

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APPENDIX A. NMT PROGRAM

Table A1.

Soccer Players	Week 1: on floor Week 2: on green foam stability trainers Weeks 3 and 4: on blue foam stability trainers
Day 1	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS partner perturbation: 30 s	2 min
4. SLS roll ball L↔R: 30 s	1 min
5. SLS roll ball front ↔ back: 30 s	1 min
Day 2	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS pass with partner: 30 s	2 min
4. SLS tip-toe: 30 s	1 min
5. SLS volley: 30 s	1 min
Day 3	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS jump: 30 s	1 min
4. Ladder drills: 2× each -in and out/scissor jumps -SL hops forward/sideways each way	2 min
Weeks 5 and 6: On Black Wobble Board	
Day 1	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS partner perturbation: 30 s	2 min
4. SLS roll ball L↔R: 30 s	1 min
5. SLS roll ball front↔back	1 min
Day 2	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS pass with partner: 30 s	2 min
4. SLS tip-toe: 30 s	1 min
5. SLS volley: 30 s	1 min
Day 3	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS: roll front back	1 min
SLS: roll L↔R	1 min
SLS: roll in circle	30 s
4. Ladder drills: 2× each -in and out/scissor jumps -SL hops forward/sideways each way	2 min

APPENDIX B. NMT PROGRAM

Table A2.

Volleyball Players	Week 1: on floor Week 2: on green foam stability trainers Weeks 3 and 4: on blue foam stability trainers
Day 1	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS partner perturbation: 30 s	2 min
4. SLS throw and catch: 30 s	1 min
5. SLS jump: 30 s	1 min
Day 2	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS pass with partner: 30 s	2 min
4. SLS tip-toe: 30 s	1 min
5. SLS set to self: 30 s	1 min
Day 3	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS jump: 30 s	1 min
4. Ladder drills: 2× each	2 min
-in and out/scissor jumps	
-SL hops forward/sideways each way	
Weeks 5 and 6: On Black Wobble Board	
Day 1	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS partner perturbation: 30 s	2 min
4. SLS throw and catch: 30 s	1 min
5. SLS diagonal reach above head: 30 s	1 min
Day 2	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS pass with partner: 30 s	2 min
4. SLS tip-toe: 30 s	1 min
5. SLS set to self: 30 s	1 min
Day 3	
1. SLS: 30 s	1 min
2. SLS with eyes closed: 30 s	1 min
3. SLS: roll front↔back	1 min
SLS: roll L↔R	1 min
SLS: roll in circle	30 s
4. Ladder drills: 2× each	2 min
-in and out/scissor jumps	
-SL hops forward/sideways each way	