Coach Education Improves Adherence to Anterior Cruciate Ligament Injury Prevention Programs: A Cluster-Randomized Controlled Trial

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Abstract

Objective: To determine the effect of an educational workshop on adherence to neuromuscular training (NMT) among high-school coaches. **Design:** Cluster-randomized controlled trial. **Setting:** High school. **Participants:** A total of 21 teams in 8 high schools (unit of randomization) were randomized to the intervention or control group. Twelve boys' and 9 girls' teams in a variety of sports were enrolled. **Intervention:** Coaches in the intervention group participated in a 60-minute education workshop to teach effective implementation of a NMT program and also received print materials. Coaches in the control group received the same print materials. **Main Outcome Measures:** Eight data collectors were trained to observe each team's practice/game 2 to 3 times a week. They completed a study questionnaire to identify the NMT exercise and whether the coach (1) delivered exercise instructions and (2) provided alignment cues (both yes/no). **Results:** A total of 399 practices/games were observed over 2 seasons. A greater proportion of coaches in the intervention group provided alignment cues to correct improper technique compared with the control group {difference = 0.04 [95% confidence interval (CI), 0.01-0.07], $P = 0.006$}. There was a similar proportion of coaches in the intervention and control groups who provided exercise instructions [difference = 0.01 (95% CI, −0.02 to 0.04), $P = 0.44$]. More coaches in the intervention group completed a full NMT program [OR = 4.62 (1.22, 17.50), $P = 0.02$]. **Conclusions:** Coach education can improve adherence to a NMT program and delivery of alignment cues. Coaches should receive in-person training on NMT and how to deliver alignment cues to their athletes while performing the exercises.

Key Words: ACL, adherence, injury prevention, neuromuscular training

(*Clin J Sport Med* 2021;00:1–7)

INTRODUCTION

Athletes face a number of health, psychological, and time costs when they suffer an anterior cruciate ligament (ACL) injury.[1,2] Returning to play can be a long process, typically taking up to a year or more, and there is no guarantee that athletes will be able to return to their previous level of performance. Ardern et al[3] reported that only 66% of athletes who sustained an ACL injury returned to sports and even fewer (45%) returned to their original sport at a competitive level. Despite improvements in ACL reconstruction and rehabilitation, the ideal strategy is to avoid these injuries altogether by using risk-reduction programs, especially in young athletes.

It is estimated that there are 250 000 ACL injuries per year in the United States alone.[4] In the early 2000s, it was estimated that 100 000 to 175 000 reconstructions were performed each year, and ACL injury rates continue to rise.[5,6] In an economic impact study, neuromuscular training programs (NMT) reduced injuries and healthcare costs by 40% when compared with standard warm-up routines after one season of implementation.[7] Although the efficacy of NMT programs in reducing ACL injuries has been clearly demonstrated,[8] difficulties remain with respect to adherence with program recommendations that hinder their real-world impact. A meta-analysis of adherence with ACL injury prevention studies found that injury rates were lower in studies with higher adherence.[9] However, this article reported that adherence was less than 50% in most studies. Thus, although the literature notes that adherence is an important aspect of successful injury prevention, sports medicine experts have had difficulty convincing athletes and coaches to faithfully perform the NMT exercises.

Research on strategies to improve adherence is lacking compared with the numerous studies showing the efficacy of injury prevention programs. More implementation research is needed to directly evaluate strategies for improving adherence rates. One study showed that the injury beliefs of players and

Submitted for publication October 14, 2020; accepted March 25, 2021.

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This study was funded by a Clinical Outcomes Research Grant from the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS).

R. G. Marx reports personal fees from the Journal of Bone and Joint Surgery, personal fees from the Journal of Bone and Joint Surgery Evidence Based Orthopedics, personal fees from Springer and Demos Health, and personal fees from Mend, outside the submitted work. The remaining authors report no conflicts of interest.

Data are available on reasonable request.

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.cjsportmed.com).

http://dx.doi.org/10.1097/JSM.0000000000000936

coaches did not affect adherence.[10] Another study using a concept mapping approach to identify barriers to implementation of FIFA 11+ among coaches found that lack of knowledge was rated highest for importance and feasibility.[11] Coaches often lack access to the knowledge and skills that are required to teach the exercises or to correct faulty technique. One study has reported that a preseason coach education workshop was effective in improving adherence to the FIFA 11+ program in female soccer players compared with web-based delivery of the program. In addition, the authors found that on-field supervision by a PT during the season did not further improve adherence,[12] indicating that coach education was the main contributing factor. Empowering them with this training may help overcome the barriers to adherence to achieve sustained ACL injury reduction in young athletes.

This cluster randomized controlled trial (RCT) evaluated the impact of a coach education program on adherence to NMT recommendations by directly observing the warm-up sessions of high-school sports teams. We hypothesized that adherence will be greater among high schools that are randomized to the intervention group with respect to the following parameters: giving exercise instructions and providing alignment cues (primary outcomes) and completing a full NMT program (secondary outcome).

METHODS

Study Enrollment

Recruitment was performed by emailing athletic directors of schools in the area which have relationships with our institution. Schools that had already implemented ACL injury prevention programs were excluded. One school was excluded for this reason. High schools were randomized to either the intervention or control arm group using a statistician-generated allocation sequence. Allocation was concealed from the study team until after the school agreed to participate. We chose to randomize by school rather than by team or coach because high-school sports coaches often work in close quarters and the risk of contamination between coaches at the same school would be high. In addition, coaches also train multiple teams within the same school. The study protocol was reviewed and approved by our institutional review board. No compensation was provided to the schools.

Study Intervention

We used a series of NMT routines (beginner, intermediate, advanced, or elite) consisting of 7 to 10 exercises each. In total, there are 34 possible exercises in these NMT routines that can be customized for athletes of different ages, skill levels, and sport types (see **Supplemental Data File 1, Supplemental Digital Content 1**, http://links.lww.com/JSM/A268). Each routine combines the key elements of multiple, validated injury prevention programs, including the FIFA 11+[13] and PEP[14] programs. Most of the NMT programs that have been developed are sports-specific or do not include all elements that have demonstrated efficacy and can serve as an effective preactivity warm-up. We determined that a comprehensive NMT session that serves as a warm-up before athletic activity should include exercises/activities from 5 distinct categories: movement preparation, core stability (the coordinated utilization of musculoskeletal and neurocognitive systems to mitigate mechanical forces during static positions and dynamic activities), lower-extremity strengthening, plyometrics, and agility. The routines can be completed in 10 to 15 minutes and are designed to replace the usual warm-up exercises at the beginning of practices and games.

Coaches from schools randomized to the intervention group received informational materials and participated in an education workshop before the start of the season. This workshop was delivered by a certified strength and conditioning specialist, who are clinicians who apply scientific knowledge to train athletes for improving athletic performance, conduct sport-specific training, and provide guidance regarding nutrition and injury prevention. The workshop consisted of a 15-minute didactic presentation and a 45-minute practical demonstration of how to effectively implement the NMT program, including proper delivery of exercise instructions and alignment cues to correct improper exercise technique. During the workshop, coaches were taught to choose the most appropriate NMT routine for their team based on the age and skill level of their athletes and to complete the full routine. A video of the workshop was made available only to the coaches in the intervention group so that they could refer to the materials throughout the season.

Feedback regarding proper technique and movement quality was also a key component of the NMT program. Coaches were trained to differentiate between exercise instruction and alignment feedback, which involves the administration of corrective cues (visual and verbal) to improve movement technique.[15–18] The coaches were instructed on how to evaluate athletes' technique for correct posture, core control, and lower-extremity alignment and provide cues on how to better perform the exercises. This assessment was performed on the upper (head and cervical-thoracic spine), middle (lumbopelvic complex), or lower body (lower extremities). Using the lower body as an example, proper alignment would be assessed on the hip, knee, and ankle.

Our intervention has a foundational basis in the theory of planned behavior, which states that one's intention to perform a behavior is based on (1) attitudes toward the behavior, (2) perceived control over the behavior, and (3) subjective norm.[19] Subjective norm, or the social pressure to perform certain behaviors, has been shown to be the strongest factor for implementing clinical guidelines.[20]

Coaches from schools randomized to the control group received the same informational materials on the NMT exercises provided to the intervention group coaches by email shortly before the start of the season. All coaches knew that they would be observed but did not know the purpose of the study.

Data Collection

The primary outcome was coach adherence, as measured by (1) delivery of exercise instructions and (2) delivery of alignment cues. A secondary outcome was delivery of a full NMT program. Eight trained data collectors were hired as outside observers on a per-diem basis to determine if coaches instructed the athletes on how to perform the NMT exercises and if alignment cues were provided by the coach to improve exercise technique. Before the start of the study, all data collectors viewed the video of the education workshop at an in-person training session and reviewed the study questionnaire that they would be complete at each observation. Each data collector was responsible for 1 to 2 teams per season and was blinded to which group their team was allocated. Each team enrolled in the study was observed 2 to 3 times a week throughout the regular season at practices and games. Data collectors were also evaluated by a study team member at random visits that were made at the beginning, middle, and end of each season. At these evaluations, both the data collector and the study team member completed the study questionnaire to assess interobserver reliability.

Data collection included recording which NMT exercises were performed during each warm-up routine. For each exercise, data collectors answered 2 questions. (1) Did the coach provide instructions explaining how to perform the exercise? (2) Did the coach provide alignment cues to encourage proper exercise technique? Once the NMT program was completed, data collectors also recorded whether a full NMT program was completed, which was defined as at least 7 exercises because this was the fewest number of exercises among the recommended NMT routines.

The inter-rater reliability between the data collectors and study team members at random visits was measured using the Kappa statistic with the following scale for levels of agreement: 0 to 0.2 slight, 0.21 to 0.4 fair, 0.41 to 0.6 moderate, 0.61 to 0.8 substantial, and 0.81 to 1 almost perfect.[21]

Statistical Analysis

Adherence was defined as whether or not the coach provided exercise instructions and alignment cues. Each individual NMT exercise performed during the warm-up routine was judged in a binary fashion as to whether instructions were provided or cues were given (yes/no). Adherence was operationalized with the following measures: cumulative utilization for each exercise (proportion of total sessions possible), utilization fidelity (average # of exercises completed per NMT session), and exercise fidelity by coaches (proportion of giving exercise instructions and alignment cues).

To adjust for potential correlation among teams at the same school, generalized estimating equations (GEEs) were used to compare the proportions between the intervention and control groups for both administration of exercise instruction and alignment cues. The GEE model accounts for both within-cluster (random error) and between-cluster variability (heterogeneity). Thus, this approach would give more conservative estimates with wider confidence intervals.

For individual exercise adherence and completion of a full NMT routine (both binary variables), a logistic GEE model was developed for practices/games within the team level within the school level. For the total number of observations across different exercises, a linear GEE model was developed for the proportion of instructions or cues that were administered at each practice/game within the team level within the school level. GEE models were not used when there were 0 cells or <5 observations for an individual exercise.

In a sensitivity analysis, GEE modeling was performed with adjustment for sex, game, or practice and sport type (cutting/pivoting or not) to determine the effect of these potential confounders on the results. In a post-hoc power analysis, with a sample size of 4 schools with an average of 3 teams in each group and assuming a difference of 3% with SD = 2%, we have 85% power to detect a difference between groups.

Patient and Public Involvement

It was not possible for participants to be involved in this research study.

RESULTS

High-school sports teams in basketball, volleyball, baseball, softball, track and field, and lacrosse were enrolled (Figure 1). A total of 399 practices or games and 2579 exercises were observed by the data collectors over 2 seasons (winter and spring). The number of observations per team ranged from 3 to 32 (median 18). The most frequently used exercises (cumulative utilization) in the intervention group were as follows: jogging forward and backwards, side shuffle, leg cradles, lunge, side plank, and figure 8 run. For exercise fidelity, the proportion of coaches who administered exercises instruction ranged from 12% to 16% (median 13%), and the proportion of alignment cues ranged from 9% to 20% (median 14%). The most frequently used exercises (cumulative utilization) in the control group were as follows: jogging forward and backwards, straight leg march, knee hugs, lunge, side shuffle, and carioca. There was greater variation in the control group compared with the intervention group for exercise fidelity, as the proportions of coaches who administered instructions and alignment cues ranged from 9% to 36% (median 22%) and 1% to 17% (median 7%), respectively (Tables 1 and 2). Coaches in the intervention group used 7 exercises per session (utilization fidelity, 1723 total exercises/246 observed sessions), whereas the coaches in the control group used 5.6 exercises per session (utilization fidelity, 856/153). Exercises from the latter phases of the NMT program (lower extremity strengthening, plyometrics, and agility) were more frequently used in the intervention group compared with controls.

When considering all of the exercises combined in the linear GEE model, a greater proportion of coaches in the intervention group provided alignment cues to correct improper technique compared with the control group {difference = 0.04 [95% confidence interval (CI), 0.01-0.07], $P = 0.006$}. From Table 2, all of the statistically significant comparisons indicated that more cues were given in the intervention group. In addition, more coaches in the intervention group completed a full NMT program [OR = 4.62 (95% CI, 1.22-17.50), $P = 0.02$] across the total number of observed practices and games. A similar proportion of coaches in the intervention group provided exercise instructions compared with the control group [difference = 0.01 (95% CI, −0.02 to 0.04), $P < 0.44$]. When evaluating the inter-rater agreement between the data collectors and study team members throughout the seasons, the Kappa values for exercise instruction and alignment cues were 0.89 and 0.90, respectively, indicating almost perfect agreement.

The results of the sensitivity analysis that adjusted for sex, game/practice, and sport type did not change our main findings: delivery of cues [difference = 0.04 (95% CI, 0.01-0.07, $P = 0.004$)] and delivery of instructions [difference = 0.02 (95% CI, −0.01 to 0.04, $P = 0.32$)]. The results for completion of a full NMT program remained similar: OR = 5.3 (95% CI, 1.11-24.78, $P = 0.04$).

DISCUSSION

We found that an education workshop resulted in a significantly higher proportion of high-school coaches

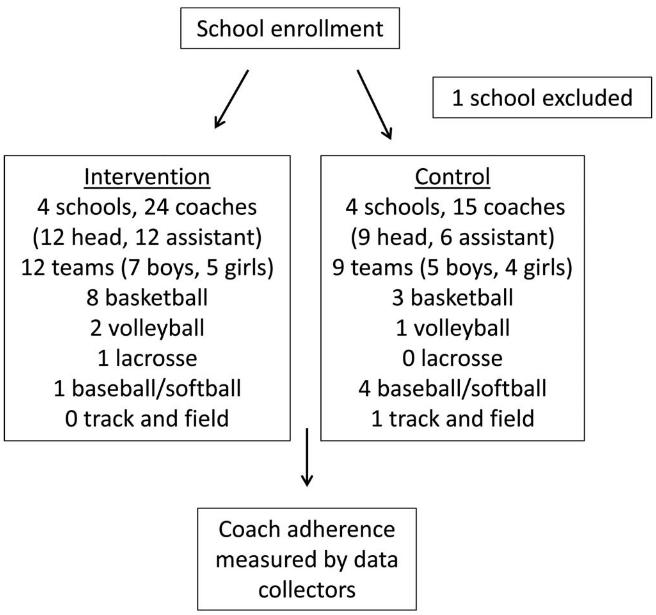

Figure 1. Flowchart of teams in the intervention and control groups. Coaches include both the head and assistant coaches.

giving alignment cues and completing full NMT routines in the intervention group compared with the control group. However, there was no difference in the use of exercise instructions between the 2 groups. Although the number of recommended exercises performed during each session was similar between groups, an interesting finding was that more coaches from the intervention group chose exercises from the latter phases of the NMT program. This finding suggests that the education workshop was effective in getting coaches to incorporate more advanced exercises. Overall, however, the proportion of coaches who delivered exercise instructions and alignment cues remained low. Although the difference in groups for delivery of alignment cues was statistically significant, the low value may not be clinically significant.

The optimal risk management strategy for noncontact ACL injuries is to prevent them from occurring.[14,22] Although there is substantial evidence to support injury prevention programs, widespread implementation has been challenging.[23,24] A recent study showed that coach adherence rates were low (32%) despite initial enthusiasm from high-school athletic directors after attending an educational seminar on the FIFA 11+ program.[25] In this study, the coaching staff was given the FIFA 11+ website, a manual, poster, and cue cards, which is a passive form of implementation. Our intervention is based on active learning with a hands-on demonstration of NMT exercises, which is often missing from delivery strategies. Few studies have directly addressed the issue of low adherence to NMT recommendations by evaluating interventions that may help increase the implementation of these programs. Adherence, which is the measure of compliance in real-world settings, can be influenced by social and behavioral contexts, such as personal knowledge, motivation, skills, and resources.[19,20,26] The major strategy of this study focused on education for coaches on how to implement a NMT program.

Our findings indicate that coach education led to an increase in the frequency with which alignment cues were implemented. This change in behavior was likely because the workshop provided coaches with the tools to first identify high-risk movement patterns and then provide the necessary feedback to correct faulty technique. Providing exercise instruction alone will minimize the beneficial impact of NMT programs on injury reduction. Several studies have shown that providing alignment cues has beneficial effects on reducing ACL injuries,[27–29] including a meta-regression that found the use of feedback to be one of the critical components of NMT programs that resulted in significant injury reduction.[30] In one study of female handball players, the incorporation of verbal cues was one of several modifications that led to a more significant reduction in ACL injuries in the subsequent season.[31]

This study has several strengths. The first is that it is one of the few implementation studies to evaluate an intervention to increase adherence to ACL injury prevention programs as the main outcome. We also used a systematic method of data collection in which adherence was measured, and interobserver reliability was confirmed. Data collectors measured coach adherence to the recommended exercises and administration of alignment cues at each team's warm-up sessions throughout the season. It is important to note that most adherence studies have used self-report rather than direct observation, which is a major limitation.[9,32] The data collectors in this study served as unbiased observers and, unlike the team's coaches or athletic trainers, would not have a conflict of interest. In addition, our findings remained the same even after adjusting for sex, practice/game, and sport type in the sensitivity analysis.

This study also has limitations. Because of the study setting, the scope of the ethics approval did not allow for the collection of coach factors that may affect their adherence, including sex, age, experience, education level, and history of ACL injury. In addition, the outcome of this study was overall coach adherence rather than individual athlete adherence to the recommended NMT exercises. It would have been impractical, if not impossible, for one data collector to measure adherence at the athlete level when all team members are doing the exercises simultaneously. In addition, the quality of the instructions and cues provided by the coaches was not evaluated.

Another limitation is that the study also had an imbalance between the intervention and control groups for the number of coaches and sports teams. The unit of randomization for this cluster RCT was the school to avoid contamination. Although there were an equal number of schools in each arm, it is common for each cluster to have an imbalanced number of individuals between groups.[33] Similarly, there were more teams in high-risk cutting/pivoting sports for the intervention group. Coaches in the control group could have conceivably felt less inclined to administer NMT programs because their teams participated in lower-risk sports. It is possible that the difference in sport type may have led to increased adherence in the intervention group. In addition, the presence of data collectors to measure adherence may lead to a Hawthorne effect, in which participants of a study behave differently

TABLE 1. Frequency of Exercise Instructions in Intervention and Control Groups

	Intervention		Control		
	N	Instructions	N	Instructions	OR (95% CI)
Phase 1: movement preparation					
Jogging forward and backward	190	30 (15.7)	125	45 (36.0)	0.28 (0.09-0.92)
Carioca	16	3 (18.8)	52	15 (28.8)	1.00 (0.13-7.61)
Hurdle step forward and backward	15	4 (26.7)	0	0 (0.0)	
Straight leg march	60	6 (0.1)	117	19 (16.2)	0.47 (0.12-1.79)
Quad thoracic rotation	3	0 (0.0)	14	0 (0.0)	
Leg cradle	141	19 (13.5)	26	5 (19.2)	0.65 (0.14-3.02)
Knee hug	85	8 (9.4)	91	8 (8.8)	1.11 (0.23-5.43)
Phase 2: core control					
Side plank	109	14 (12.8)	21	1 (4.8)	2.91 (1.30-6.51)
Bridge walk	34	3 (8.8)	8	0 (0.0)	
Bird dog	1	1 (100)	0	0 (0.0)	
Supine bridge	16	0 (0.0)	26	6 (23.1)	
Prone extension	74	10 (13.5)	21	0 (0.0)	
Low plank	56	16 (28.5)	7	3 (42.9)	0.49 (0.28-0.88)
Phase 3: lower extremity strengthening					
Single leg forward T-exercise	89	13 (14.6)	34	4 (11.8)	1.19 (0.19-7.32)
Double leg squat	7	4 (57.1)	7	2 (28.6)	4.99 (0.74-34.07)
Single leg heel raise	2	1 (50)	16	3 (18.8)	
Lunge	125	16 (12.8)	67	15 (22.4)	0.16 (0.09-0.29)
Double leg heel raise	53	8 (13.2)	25	3 (11.5)	1.19 (0.36-3.94)
Single leg balance	12	8 (66.7)	6	2 (33.3)	4.05 (0.53,31.22)
Phase 4: plyometrics					
Double leg hop forward and backward	30	8 (26.7)	0	0 (0.0)	
Double leg hop lateral	53	11 (20.8)	0	0 (0.0)	
Scissor jump	16	2 (12.5)	21	1 (4.8)	2.52 (2.51-2.53)
Broad jump	37	4 (10.8)	2	0 (0.0)	.
Single leg hop forward and backwards	0	0 (0.0)	1	0 (0.0)	.
Single leg hop	1	1 (100)	6	3 (50.0)	.
Vertical jump	34	5 (14.7)	3	3 (100)	.
Lateral skater hop	17	1 (5.8)	26	1 (3.7)	1.59 (0.99-2.53)
Standing landing	49	10 (20.4)	2	2 (100)	.
Phase 5: agility					
Run-shuffle	0	0 (0.0)	5	4 (0.8)	
Chop and stop with jump	1	1 (100)	16	10 (62.5)	
Side shuffle	145	22 (15.2)	66	14 (21.2)	0.79 (0.22-2.92)
Shuttle run	6	2 (33.3)	11	0 (0.0)	
Figure 8 Run narrow	107	13 (12.2)	0	0 (0.0)	
Chop and stop	96	16 (16.7)	22	16 (72.7)	0.13 (0.02-0.76)
Total	1723	466 (27.0)	856	180 (21.0)	

The values show the number of observations (N, cumulative utilization), and the percentage of times instructions (%, exercise fidelity) were given for each exercise. The P-values represent the comparison between the intervention and control groups in the GEE model when feasible.

when they are being observed. This factor was present in both the intervention and control groups, thereby limiting any potential bias. Furthermore, the data collectors were not directly part of the NMT, not interacting with the athletes, and therefore unlikely to affect the coach's or team's behavior.

TABLE 2. Frequency of Alignment Cues in Intervention and Control Groups

	Intervention		Control		
	N	Alignment	N	Alignment	OR (95% CI) *P*
Phase 1: movement preparation					
Jogging forward and backward	190	24 (12.6)	125	1 (0.8)	21.32 (2.73-167.2)
Carioca	16	1 (6.3)	52	9 (17.3)	0.38 (0.05-3.23)
Hurdle steps forward and backward	15	1 (6.7)	0	0 (0.0)	
Straight leg march	60	4 (6.7)	117	2 (1.7)	1.37 (0.29-52.37)
Quad thoracic rotation	3	0 (0.0)	14	1 (7.1)	
Leg cradle	141	12 (8.5)	26	1 (3.8)	2.99 (0.55-16.39)
Knee hug	85	6 (7.1)	91	1 (1.1)	5.09 (0.55-47.28)
Phase 2: core control					
Side plank	109	22 (20.2)	21	1 (4.8)	3.64 (1.82-7.24)
Bridge walk	34	3 (8.8)	8	0 (0.0)	
Bird dog	1	1 (100)	0	0 (0.0)	
Supine bridge	16	0 (0.0)	26	3 (11.5)	
Prone extension	74	12 (16.2)	21	0 (0.0)	
Low plank	56	20 (35.7)	7	2 (28.6)	1.82 (1.17-2.82)
Phase 3: lower extremity strengthening					
Single leg forward T-exercise	89	7 (7.9)	34	1 (2.9)	3.03 (0.25-37.26)
Double leg squat	7	3 (42.9)	7	2 (28.6)	1.5 (0.23-9.9)
Single leg heel raise	2	0 (0.0)	16	1 (6.3)	
Lunge	125	20 (16.0)	67	8 (11.9)	1.26 (0.36-4.44)
Double leg heel raise	53	5 (9.4)	25	0 (0.0)	
Single leg balance	12	8 (66.7)	6	1 (16.7)	12.67 (1.96-81.85)
Phase 4: plyometrics					
Double leg hops forward and backward	30	7 (23.3)	0	0 (0.0)	
Double leg hops lateral	53	7 (13.2)	0	0 (0.0)	
Scissor jump	16	1 (6.3)	21	0 (0.0)	
Broad jump	37	10 (27.0)	2	0 (0.0)	
Single leg hop forward and backwards	0	0 (0.0)	1	0 (0.0)	
Single leg hop	1	1 (100)	6	1 (16.7)	
Vertical jump	34	10 (29.4)	3	3 (100)	
Lateral skater hop	17	0 (0.0)	26	0 (0.0)	
Standing landing	49	10 (20.4)	2	1 (50.0)	
Phase 5: agility					
Run-shuffle	0	0 (0.0)	5	2 (0.4)	
Chop and stop with jump	1	0 (0.0)	16	7 (43.8)	
Side shuffle	145	26 (17.9)	66	8 (12.1)	1.55 (0.50-4.74)
Shuttle run	6	0 (0.0)	11	0 (0.0)	
Figure 8 Run narrow	107	11 (10.3)	0	0 (0.0)	
Chop and stop	96	22 (22.9)	22	4 (18.2)	1.20 (0.55-2.60)
Total	1723	264 (15.3)	856	60 (7.0)	

The values show the number of observations (N, cumulative utilization), and the percentage of times cues (%, exercise fidelity) were given for each exercise. The P*-values represent the comparison between the intervention and control groups in the GEE model when feasible.*

CONCLUSIONS

This cluster RCT demonstrates that coach education can improve delivery of alignment cues and completion of a full NMT program, even after taking into account sex, practice/game, and sport type. Coaches should receive in-person training on the value of NMT and also on how to deliver alignment cues to their athletes while performing the recommended exercises. Future studies should include injury surveillance to evaluate the impact of coach education on this important outcome.

ACKNOWLEDGMENTS

The authors are grateful to Christopher Campbell, Nicholas Cepeda, Jeffry Guerrero, Amanda Haughney, Karen Izquierdo, Jahzyah Parache, Jacklyn Regan, and Timothy Stanton for their efforts with data collection.

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