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original research

Preventive Neuromuscular Training for Young Female Athletes: Comparison of Coach and Athlete Compliance Rates

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Context: Fewer athletic injuries and lower anterior cruciate ligament injury incidence rates were noted in studies of neuromuscular-training (NMT) interventions that had high compliance rates. However, several groups have demonstrated that preventive NMT interventions were limited by low compliance rates.

Objective: To descriptively analyze coach and athlete compliance with preventive NMT and compare the compliance between study arms as well as among school levels and sports.

Design: Randomized, controlled clinical trial.

Setting: Middle and high school athletic programs.

Participants or Other Participants: A total of 52 teams, comprising 547 female athletes, were randomly assigned to the experimental or control group and followed for 1 athletic season.

Intervention(s): The experimental group (n = 30 teams [301 athletes]: 12 basketball teams [125 athletes], 6 soccer teams [74 athletes], and 12 volleyball teams [102 athletes]) participated in an NMT program aimed at reducing traumatic knee injuries through a trunk-stabilization and hip-strengthening program. The control group (n = 22 teams [246 athletes]: 11 basketball teams [116 athletes], 5 soccer teams [68 athletes], and 6 volleyball teams [62 athletes]) performed a resistive rubber-band running program.

Main Outcome Measure(s): Compliance with the assigned intervention protocols (3 times per week during the preseason [mean = 3.4 weeks] and 2 times per week in-season [mean = 11.9 weeks] of coaches [*coach compliance*] and athletes [*athlete compliance*]) was measured descriptively. Using an independent *t* test, we compared coach and athlete compliance between the study arms. A 2-way analysis of variance was calculated to compare differences between coach and athlete compliance by school level (middle and high schools) and sport (basketball, soccer, and volleyball).

Results: The protocols were completed at a mean rate of 1.3 ± 1.1 times per week during the preseason and 1.2 ± 0.5 times per week in-season. A total of 88.4% of athletes completed 2/3 of the intervention sessions. Coach compliance was greater in the experimental group than in the control group ($P = .014$). Coach compliance did not differ by sport but was greater at the high school than the middle school ($P = .001$) level. Athlete compliance did not differ by study arm, sport, or school level.

Conclusions: Athletes received instruction in about 50% of each protocol. Nearly 90% of athletes performed more than 2/3 of the assigned NMT interventions. The assigned intervention was performed more often in the experimental arm compared with the control arm. Coaches at the high school level complied with the given protocol more than middle school coaches did. Athletes complied well with the protocol, but coaches did not, especially at the middle school level.

Key Words: athletic injuries, knee, anterior cruciate ligament, high school, middle school

Key Points

- Coaches practiced only 50% of the assigned neuromuscular-training (NMT) intervention sessions.
- Nearly 90% of athletes complied with more than 2/3 of the NMT interventions.
- Busy competition schedules and a lack of available time during the season might have hindered compliance with the protocol among coaches, especially at the middle school level.
- Identifying applicable strategies for successful implementation of preventive NMT and maintaining high compliance rates among coaches are key.

Adherence and *compliance* are terms often used to describe the ability to follow given tasks. For neuromuscular-training (NMT) intervention studies, compliance with the protocol is an important variable when determining the success and usefulness of these programs.[1] Many groups[2–15] have measured the effect of NMT compliance in reducing knee-injury rates. Using a prospective, cluster-randomized controlled design, other investigators[16] assessed compliance in 52 young female soccer teams (a total of 1055 players) who participated in a comprehensive soccer specific warm-up program called 11+. Athletes who displayed a high level of compliance showed a 35% lower overall injury incidence compared with athletes who displayed an intermediate compliance level. Similarly, athletes with a high level of compliance experienced a 39% lower incidence of acute soccer injuries than athletes with intermediate compliance levels. Authors[1] who compared anterior cruciate ligament (ACL) injury incidence rates among 6 NMT studies (using a binary incidence rate ratio analysis) found that those who demonstrated a high level of compliance had a 73% lower ACL injury incidence rate than those with low compliance levels. Their tertile incidence rate ratio analysis identified an ACL injury incidence rate in those with a high level of compliance that was 82% lower than those with moderate or lower levels of compliance. Both analyses demonstrated the effect of NMT compliance on ACL injury incidence rates.

Although past researchers[1,16] studied the effect of compliance with NMT intervention on athletic injuries, a few groups[7–11,17,18] did not report NMT compliance in the original manuscripts. Other authors[2,3] cited low NMT compliance as a limitation of their experiments that hindered outcomes. Reporting of compliance and the effect of NMT compliance are not well documented, are often neglected in analysis, and are not emphasized in most study designs. There is no standard reporting method for compliance rate in NMT research, which may be why this factor is not often reported.

Therefore, we sought to analyze 2 types of compliance measures: compliance of coaches with the given study protocol and compliance of athletes with the given NMT interventions. The current study with 2 arms (experimental versus control group) was performed as a secondary analysis to determine the prophylactic effectiveness of preventive NMT on knee injuries in young female athletes. Our main purpose was to analyze compliance with a preventive NMT protocol in coaches and athletes by (1) descriptively analyzing coach and athlete compliance with the study protocol, (2) examining coach and athlete compliance between the study arms, and (3) comparing coach and athlete compliance based on school level and sport.

METHODS

Study Design

A prospective cluster-randomized controlled trial was used to examine the effects of trunk- and hip-focused NMT on knee injuries in young female athletes. The clusters were girls' soccer, volleyball, and basketball teams in middle and high schools. Each team was randomly assigned to either an experimental group (core integrative NMT) or a control group (speed and agility training). The sample-size estimation and randomization were performed independently by a statistician who maintained the concealment; all other research team members, including the principal investigator, outcome assessors, research assistants, and intervention providers, were blinded. In addition, the current trial followed an intention-to-treat (ITT) protocol. The ITT protocol assured that none of the participants was excluded once it was randomized.[19] The purposes of the ITT protocol are to preserve the random allocation of the trial[20] and avoid bias associated with nonrandom loss of participants.[21]

Participants

Athletes and coaches from a total of 52 teams (547 athletes), consisting of female basketball (23 teams, 241 athletes), soccer (11 teams, 142 athletes), and volleyball (18 teams, 164 athletes) teams at public middle and high schools agreed to participate in this study. To reduce bias, coaches and athletes were blinded to the randomization.

Training Protocol

Both interventions were initiated in the preseason and continued until the end of postseason play. The individuals providing the allocated interventions were mainly coaching staff (n = 39, 83.0%) but also several certified athletic trainers (n = 4, 8.5%) and specially trained undergraduate college students (n = 4, 8.5%) in sports medicine-associated programs. All intervention providers attended mandatory education and training sessions before and during the intervention. These sessions for the experimental and control intervention providers took place separately to maintain blinding and consisted of 60-minute overviews of exercise demonstrations and injury-tracking and reporting methods.

The core integrative NMT program involved a series of exercises designed to target trunk stabilization and improve hip strength and power; the specific exercises were previously documented.[22] They included lower extremity strengthening, jump-landing maneuvers, and trunk stabilization as derived from previous researchers[2,7,9,23,24] who demonstrated decreased injury incidence rates and improved neuromuscular control after their use. The core integrative NMT level of intensity, difficulty, and techniques were progressed throughout the season. The intervention providers were asked to implement the program (13 exercises, single set, 4–15 repetitions depending on the exercise) for 15 to 30 minutes, 3 times per week, during the preseason. Once teams began the in-season regimen, the core integrative NMT was shortened to 10 to 15 minutes, 2 times per week (7 exercises, single set, 3–10 repetitions depending on the exercise).

The duration and frequency of the speed-and-agility training were the same as for the core integrative NMT program. The speed-and-agility training used a rubber band (medium strength; Jump Strength Inc, Youngstown, OH), which was secured around the participant's waist to provide resistance. Then she was asked to run forward and backward while tension was placed on the rubber band to provide resistance. This training method was reported to enhance sprint start speed and increase stride frequency in young female athletes.[25] The speed-and-agility training consisted of 8 to 10 different styles of rubber-band running, including backward and high-knees techniques at slow, moderate, and fast speeds. The speed-and-agility training was implemented in the control group as a placebo and to

Table 1. Example of Individual Athlete Compliance Form

	Session 1	Session 2	Session 3	Session 4	Session 5	Individual Compliance
Athlete A	✓	✓		✓	✓	4
Athlete B	✓	✓	✓	✓	✓	5
Athlete C	✓		✓		✓	3

reduce bias between groups, especially when other interventions at the same school were different.

Compliance Tracking

The intervention providers were asked to record each participant's attendance and completion of exercises at the end of each session. If a participant did not finish the assigned exercises in a session, this was defined as *not being compliant* for that session. The study coordinator contacted each intervention provider weekly and collected the compliance information through e-mail using an Excel (version 2010; Microsoft Corp, Redmond, WA) spreadsheet attachment. When the compliance information was not obtained, the study coordinator made a subsequent request to the intervention provider.

Compliance Rate Calculation

The compliance calculation started with the first intervention session of the preseason and continued through the last intervention session of the in-season. Each intervention provider's compliance was examined based on the study protocol (3 times per week during the preseason and 2 times per week in-season) and how many times the intervention was delivered. The coach compliance rate was defined as follows:

Coach compliance (%) = Summation of intervention sessions delivered during preseason and in-season/summation of maximum intervention sessions that could be delivered according to the study protocol.

Individual athlete compliance was believed to be the most reflective variable of NMT activity engagement. The individual athlete compliance form is shown in Table 1 and was completed by intervention providers each time the intervention was delivered. The individual athlete compliance was calculated as follows:

Athlete compliance (%) = Proportion of individuals on roster who attended and completed more than 2/3 of intervention sessions that were delivered by intervention providers during preseason and in-season.

We selected the cutoff value of 2/3 of intervention sessions because previous authors[1] indicated that once compliance with NMT decreased to 2/3, NMT was not prophylactically effective.[4]

Statistical Analysis

All teams were randomized, and characteristics of each group (core integrative versus speed and agility training)

Table 2. Demographic Information for Experimental and Control Groups

Characteristic	Variable	Group, Teams (Athletes) Experimental	Control	*P* Value
Sport, no.	Average	30 (244)	22 (195)	
	Basketball	12 (97)	11 (92)	
	Soccer	6 (57)	5 (44)	
	Volleyball	12 (90)	6 (59)	
Physical characteristics, mean ± SD	Height, cm	160.9 ± 8.5	160.4 ± 7.9	.525
	Weight, kg	54.1 ± 11.8	55.5 ± 13.1	.267
	Body mass index	20.7 ± 3.5	21.3 ± 4.2	.155
	Age, y	13.9 ± 1.7	13.8 ± 1.7	.486
Age distribution, y	11	51	23	
	12	37	33	
	13	52	44	
	14	42	44	
	15	32	27	
	16	20	16	
	17	8	8	
	18	2	0	
Pubertal status	Prepubertal	22	7	
	Pubertal	125	113	
	Postpubertal	97	75	
Previous knee injuries?	Yes	43	33	
	No	201	162	
Previous knee surgeries?	Yes	1	1	
	No	243	194	
Previous participation in injury-prevention program?	Yes	28	21	
	No	216	174	
Previous participation in performance-enhancement program?	Yes	74	54	
	No	170	141	

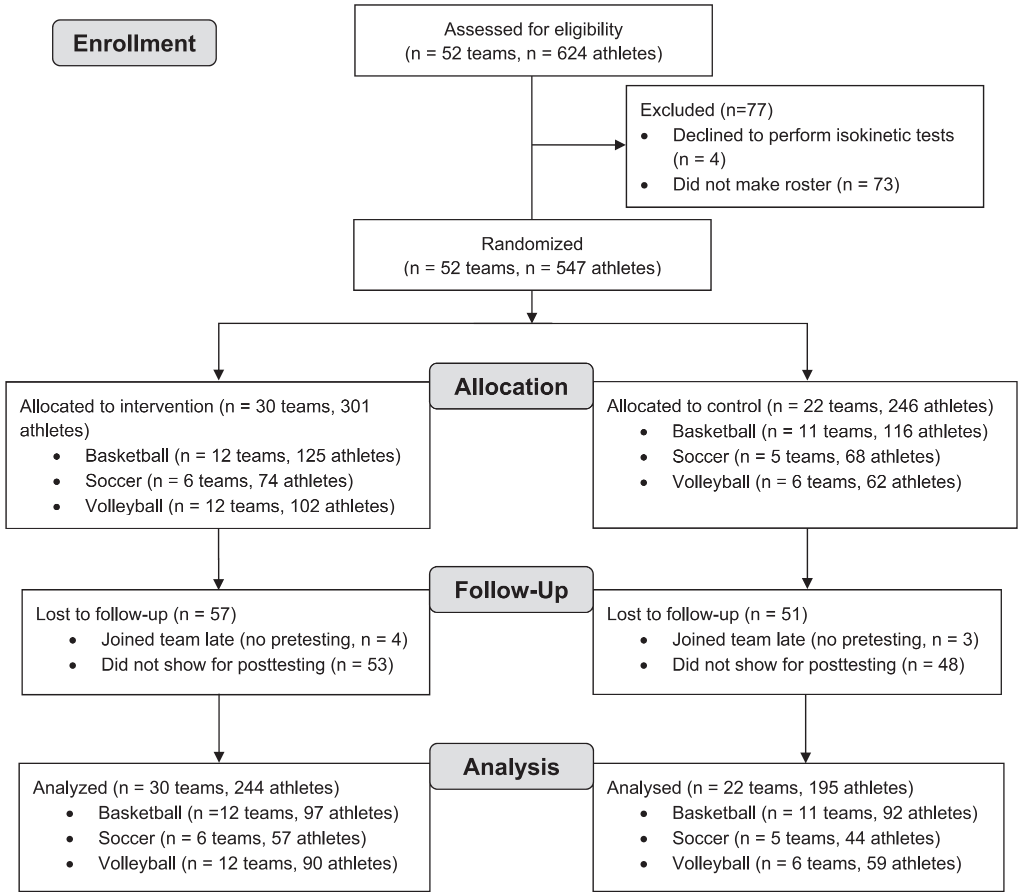

Figure. Study flow diagram.

are listed in Table 2. Independent *t* tests were performed for height, weight, body mass index, and age. The α level for the independent *t* test was set a priori at .05.

For aim 1, we used descriptive statistics to analyze coach and athlete compliance rates between the study arms. To examine aim 2, independent *t* tests were performed to examine differences in coach and athlete compliance rates between the study arms, and the a priori α level was set at .05. To attain aim 3, both compliance rates were analyzed based on school level (middle or high school) and sport (basketball, soccer, or volleyball) using a 2-way analysis of variance. Bonferroni post hoc tests were employed to adjust for multiple comparisons.

RESULTS

A total of 30 teams (12 basketball, 6 soccer, and 12 volleyball teams) were assigned to the core integrative NMT group and 22 teams (11 basketball, 5 soccer, and 6 volleyball teams) were assigned to the speed-and-agility training group (Figure).

Group Demographic Descriptive Statistics

Demographic descriptive statistics for the groups are found in Table 2. Height, weight, body mass index, and age did not differ on pretest measures.

Aim 1: Coach Compliance With Protocol. Coach compliance with the given protocol was 52.5% ± 11.7%. The intervention was implemented at a mean rate of 1.3 ± 1.1 times per week during the preseason and 1.2 ± 0.5 times per week in-season.

Aim 1: Athlete Compliance With Intervention. Athlete compliance with the intervention was 87.8% ± 10.6%. During the study, 88.4% of athletes completed more than 2/3 of all the intervention sessions.

Aim 2: Coach Compliance Between the Experimental and Control Groups. Coach compliance was greater in the core integrative NMT group than in the speed-and-agility training group ($P = .014$; Table 3). Coach compliance during the preseason did not differ between groups; however, greater compliance was recorded in-season for

Table 3. Intervention Sessions Performed and Coach Compliance in Experimental and Control Groups

		Group, Mean ± SD		
Season	Variable	Experimental	Control	*P* Value
	Total sessions	20.4 ± 7.6	15.7 ± 5.1	.014[a]
	Compliance, %	58.8 ± 18.7	44.1 ± 11.8	
Preseason				
	Total sessions	5.5 ± 5.1	4.3 ± 3.5	
	Sessions/wk	1.4 ± 1.2	1.1 ± 1.0	
	Compliance, %	46.5 ± 39.1	36.1 ± 32.6	.357
In-season				
	Total sessions	14.9 ± 10.6	11.4 ± 3.8	
	Sessions/wk	1.3 ± 0.5	1.0 ± 0.3	
	Compliance, %	64.6 ± 24.7	47.4 ± 16.2	.022[a]

[a] $P < .05$.

Table 4. Athlete Compliance in Experimental and Control Groups

Group, Mean ± SD (%)		
Experimental	Control	*P* Value
87.1 ± 10.6	88.8 ± 11.2	.602

the core integrative NMT group compared with the speed-and-agility training group ($P = .022$; Table 3).

Aim 2: Athlete Compliance Between the Experimental and Control Groups. Athlete compliance did not differ between the core integrative NMT and speed-and-agility training groups ($P = .602$; Table 4).

Aim 3: Coach Compliance Based on School Level and Sport. There was no interaction between school level and sport ($P = .348$; Table 5) and no main effect of sport ($P = 0.867$; Table 5). However, coach compliance was greater in middle schools than in high schools ($P = .001$; Table 5).

Aim 3: Athlete Compliance Based on School Level and Sport. There was no interaction of school level and sport ($P = .833$; Table 6) and no main effect of school level ($P = .359$; Table 6) or sport ($P = .733$; Table 6).

DISCUSSION

The main purpose of our study was to analyze coach and athlete compliance with interventions designed to reduce traumatic knee injuries in young female athletes. Coach compliance with the protocol was 52.5% ± 11.7%, which is a mean rate of 1.3 ± 1.1 times per week during the preseason and 1.2 ± 0.5 times per week in-season. The study protocol was to provide the assigned intervention 3 times per week during the preseason and 2 times per week in-season. The rate of the intervention as instructed by the coach was unexpectedly lower. Low levels of compliance with NMT protocols were documented in past investigations.[2,3] One strategy used in previous work to enhance compliance with NMT was to have noncoaching personnel take a supervisory role in the interventions.[2] In our study, most of those who provided the intervention were coaches (n = 39, 83%); 8 intervention providers were noncoaching staff members (4 certified athletic trainers and 4 undergraduate college students). Thus, we assessed whether the teams under the noncoach intervention providers demonstrated higher compliance. However, compliance with the assigned intervention did not differ for coach versus noncoach intervention providers (57.3% ± 14.5% led by coaches versus 53.3% ± 23.0% led by noncoaches, $P = .638$). One certified athletic trainer in this study mentioned that the assigned intervention was sometimes omitted at the coaches' discretion even though the athletic trainer was available to deliver the prescribed intervention. This comment exemplified that some coaches chose not to follow the protocol and that coaches have strong authority to determine how practice time is used. Therefore, gaining coaches' understanding through communication is a key to successful implementation of the protocol.

The different levels of coach compliance between the study arms were not expected. In this study, the speed-and-agility training intervention served the purpose of sham training because the randomization was performed at the team level but not at the school level. Previous researchers[25] reported an increase in sprint start speed after the speed-and-agility training program. The exercises incorporated in the speed-and-agility training program placed more emphasis on the performance aspects of training, so we expected better coach compliance with this group. However, the core integrative NMT intervention was practiced a total of 20.4 times in the experimental group compared with 15.7 times by the speed-and-agility training group during a season (Table 3), and the difference appears to stem from the in-season compliance rates. The core integrative NMT intervention was performed approximately 15 times in-season (mean of 1.3 times per week; Table 2), yet the speed-and-agility training intervention was implemented only 11 times in-season (mean of 1.0 time per week; Table 3). Given the lack of difference in the number of interventions implemented between the study arms during the preseason, the in-season compliance rate difference likely influenced the overall season compliance rates (Table 3). According to our research associates working on site, a few coaches commented that limited practice schedules did not allow them to follow the study protocol (3 times per week during the preseason and 2 times per week in-season), especially in-season. The reasons for the limited practice schedules varied, but the most common reason was tight competition schedules. For instance, when 2 competitions were scheduled during weekdays, only 3 days were available to perform the prescribed intervention, but 1 or 2 of those days were often used for rest and recovery, which made following the in-season protocol (2 times per week) difficult. For this reason, we carried out an extra analysis to investigate if the number of athletic competitions between the study arms differed. Indeed, the speed-and-agility training group had more athletic competitions (an average of 24.0) compared with the core integrative NMT group (an average of 22.4; Table 7). Therefore, more athletic competitions might have reduced opportunities to perform the speed-and-agility training intervention in the control arm, which in turn might have led to the higher level of coach compliance in the experimental arm.

Table 5. Intervention Sessions Performed and Coach Compliance By School Level and Sport,[a] Mean ± SD

		School	
Sport	Variable	Middle	High
Basketball	Total	17.1 ± 5.1	25.1 ± 5.1
	Compliance, %	44.1 ± 13.0	63.8 ± 12.0
Soccer	Total	8.0 ± 1.4	19.6 ± 5.9
	Compliance, %	33.3 ± 5.9	73.1 ± 25.0
Volleyball	Total	6.7 ± 1.5	18.6 ± 7.0
	Compliance, %	33.3 ± 7.6	58.0 ± 25.8

[a] The interaction was not significant ($P = .348$). The main effect for school level was significant ($P = .001$), but the main effect of sport was not significant ($P = .867$).

Table 6. Athlete Compliance By School Level and Sport,[a] Mean ± SD (%)

	School	
Sport	Middle	High
Basketball	84.2 ± 10.2	87.1 ± 13.3
Soccer	87.7 ± 7.1	90.9 ± 8.0
Volleyball	91.4 ± 12.8	92.1 ± 0.7

[a] Neither the interaction ($P = .833$) nor the main effect of school level ($P = .733$) or sport ($P = .359$) was significant.

Table 7. Athletic Competitions of Experimental and Control Groups, Mean ± SD

Number of Competitions	Group: Experimental	Group: Control	*P* Value
Average	22.4 ± 6.4	24.0 ± 4.8	.002[a]
Basketball	24.6 ± 2.9	25.1 ± 3.3	.211
Soccer	17.6 ± 7.4	22.7 ± 7.1	.001[a]
Volleyball	22.9 ± 6.9	22.4 ± 3.4	.646

[a] $P < .05$.

In addition, coach compliance levels were different between the school levels but not different by sport (Table 5). The lower coach compliance levels at middle schools across all sports might be due to fewer practice opportunities compared with high schools during the preseason. In this study, a few middle school soccer and volleyball coaches mentioned that they did not have adequate time to perform the assigned interventions during the preseason. Specifically, the preseason duration of the soccer and volleyball teams at the middle school level was approximately 2 weeks compared with 4 weeks for the basketball teams, which reflected the observed results within the middle schools (Table 5). The same explanation might be applicable to the differences in coach compliance between the middle and high schools. The high school preseason is generally longer than that in middle school, so high school coaches might have had more time and opportunities to perform the assigned interventions. On the other hand, middle school coaches preferred not to spend limited practice time and opportunities on the study interventions. In short, it appeared that available time during the season plays a critical role for coaches. The analysis of coach compliance between the study arms showed the same tendencies. The tight schedules and greater number of competitions seemed to limit opportunities to perform the speed-and-agility training in the control arm. Therefore, securing available time is another important aspect to enhancing compliance with a study protocol and implementation of preventive NMT.

Athlete compliance did not differ between the study arms (Table 4). Nearly 90% of athletes who were enrolled in this clinical trial participated in more than 2/3 of the intervention sessions given, regardless of school level or sport (Table 6). The main reasons for missing the assigned NMT were being late for practices and being sick or injured. Our results offer important clinical implications: when the intervention was provided by the coaching staff, most athletes followed their instructions. Authors[2,3] of several previous preventive NMT studies have pointed out that compliance is a limitation. However, because most athletes tend to perform prescribed interventions, a key to enhancing preventive NMT compliance is to enhance coach compliance and adherence to the intervention. Researchers[26] who investigated variables influencing the implementation of preventive NMT reported that coaching experience and the presence of additional supporting staff (such as an athletic trainer or strength and conditioning specialist) may influence participation. Thus, the presence of supporting health care providers is a critical element in preventive NMT implementation and execution. In addition, these authors[26] found that performance enhancement, educational requirements, and policy changes by athletic associations were key to implementing preventive NMT intervention and maintaining high compliance among coaches. Steffen et al[27] recently compared 2 preventive NMT delivery methods: (1) a set of educational workshops for coaches and on-site assistance from physiotherapists and (2) unsupervised Web site-based education for coaches. Preventive NMT exercises were practiced almost twice as much by teams whose coaches took the educational workshops and had assistance from physiotherapists compared with teams whose coaches had access to the unsupervised Web site-based education. Also, athletes who adhered to the preventive NMT exercises at the higher level had a 57% lower injury incidence.[27]

Our study had several methodologic concerns that need to be reported. First, the cluster randomization resulted in almost equal numbers of basketball and soccer teams between the arms; however, randomization was not ideal in volleyball. Only 6 teams were allocated to the speed-and-agility training group compared with 12 teams in the core integrative NMT group (Figure). Second, cross-contamination between the training groups occurred. Several athletes were recruited to more advanced teams during the intervention period, which resulted in several participants experiencing both interventions. Because the analysis was performed under the ITT principle, we analyzed the data according to the team of initial allocation.

CONCLUSIONS

This project focused on analyzing 2 types of compliance: compliance of intervention providers with following a study protocol (coach compliance) and compliance of individual athletes with performing assigned NMT (athlete compliance). Coach compliance with the study protocol was approximately 50% and was greater in the experimental arm than in the control arm. High school coaches were more compliant than middle school coaches. Coach compliance did not differ among sports. Nearly 90% of athletes complied with more than 2/3 of the interventions, regardless of study arm, school level, or sport, which indicates that athletes can follow a given intervention. Busy competition schedules and a lack of available time during seasons might have contributed to the lower compliance level of coaches. Because previous researchers identified an inverse dose-response relationship between preventive NMT compliance and traumatic knee (ie, ACL) injury,[1,14,28] future investigators need to focus on finding practical strategies to make NMT a part of regular practice regimens. This will allow coaches to comply with and adhere to preventive NMT, which may protect young athletes from injury.

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