**Article Info**

**Keywords:**
- Anterior cruciate ligament
- Adherence
- Injury prevention
- Neuromuscular training

**Abstract**

**Objectives:** Studies on adherence to neuromuscular training (NMT) for anterior cruciate ligament (ACL) injury prevention are frequently biased due to the use of self-reporting by coaches or the athletes themselves. Few NMT studies use data collectors (aside from the athletes or the individuals administering the NMT program) to decrease bias when assessing the adherence of coaches and sports teams. We hypothesized that the use of a data collector who is independent of the team to evaluate adherence to NMT programs would be reliable.

**Methods:** In a prior a cluster-randomized controlled trial evaluating adherence to NMT training trial, twelve boys' and nine girls' high school athletic teams in a variety of sports were enrolled. Eight data collectors (unaffiliated with the NMT program) were hired specifically to record adherence of the athletes to the NMT exercises at each team's warm-ups 2–3 times a week, prior to practices and games. In addition to the data collectors, a control group of independent observers made visits throughout the season to also record adherence (solely for the purpose of this study, alongside the data collectors and in the same fashion) in order to evaluate the data collectors' performance and determine inter-observer reliability. The inter-observer reliability between data collectors and independent observers was measured using the Kappa statistic.

**Results:** A total of 399 warm-ups for practices or games were observed by data collectors to obtain adherence data. Independent observers also measured adherence at 58 practices or games for inter-observer reliability. Exercise instruction and alignment cues for 29 different exercises were analysed. The Kappa values ranged from 0.63 to 1.0, indicating substantial to perfect agreement. The overall Kappa values of 0.89 and 0.90 for exercise instruction and alignment cues, respectively, indicated almost perfect agreement.

**Conclusion:** The use of a data collector who is independent of the team to evaluate adherence to NMT programs (rather than athlete or coach self-reporting), was shown to be a reliable method for measurement of adherence in studies of NMT for injury prevention. Avoiding self-reporting in adherence research to NMT training may decrease bias.

**Level of Evidence:** 1.
What are the new findings

- The use of a data collector who is independent of the team to evaluate adherence to neuromuscular training programs is reliable and should be implemented in future neuromuscular training studies for anterior cruciate ligament injury prevention to decrease bias from self-reporting by athletes, coaches, and/or trainers.
- The overall inter-observer reliability between data collectors and a control group of independent observers as measured by the Kappa statistic indicated almost perfect agreement.
- The Kappa value indicated substantial to perfect agreement regardless of the different neuromuscular training exercises or combination of data collector and independent observer.

INTRODUCTION

It is important to reduce the risk of anterior cruciate ligament (ACL) injury in athletes because of the long recovery process, the increased risk of a second ACL injury as well as the risk of post-traumatic osteoarthritis [1–6]. Neuromuscular training (NMT) programs have been shown to be efficacious in preventing ACL injuries, especially with high adherence [7–9]. Unfortunately, if the athletes cease to perform the training, the effect is lost [7–9]. NMT programs typically include exercises that improve the athletes’ balance, proprioception, core strength, body position, and movement patterns. Examples include tuck jumps, lunge jumps, single-leg balance, and landing stabilization exercises, as described by Myer et al. [10,11]. These exercises done pre-season and in-season help to train athletes in proper technique and increase strength and balance to prevent injuries [12–14]. The ACL injury rate was also shown to decrease in middle school and high school athletes when they participated in an NMT program [12]. NMT programs are particularly important for athletes at high risk for ACL injury [15].

However, the coach and athlete adherence (i.e. compliance in a real-world setting) to NMT programs is generally poor which makes implementation a challenge [16,17]. Poor adherence, which is well documented in the literature, may explain why ACL injury rates have not decreased with the advent of NMT programs, particularly in the paediatric population [18]. There are many factors contributing to low adherence and the continued high risk of ACL injury, including conflicting priorities during the season, coach and staff changes, cost, time constraints, and also a lack of understanding of the benefits of NMT [17,19–22]. While workshops can improve coaches’ attitudes towards injury prevention programs, higher behaviour intent, perceived control, or other behaviour determinants of health were not correlated with increased compliance [23]. Strategies to increase NMT adherence include increasing the amount of personnel dedicated to injury prevention programs and changing the perception of the time required to implement NMT programs [19,20].

Typically, adherence rates in NMT studies have been self-reported by the person conducting the program (e.g. athlete, coach or athletic trainer), who is frequently inherently biased. Studies on NMT usually reduce bias by blinding both the coach and athletes as to which group they were randomized to (NMT or no NMT) [22]. The bias is not limited to only studies looking at NMT programs but has been noted by studies focusing on compliance in other sports, such as coach training recommendations and non-NMT injury prevention guidelines for baseball and swimming [24,25]. Self-reporting from coaches and athletes themselves are subject to selection bias as well as subjective and/or inaccurate memory [24,25]. We hypothesized that the use of a data collector who is independent of the team to evaluate adherence to NMT programs would be reliable.

METHODS

In a previously published cluster randomized controlled trial (RCT), we evaluated in-person coach education compared to print-only materials without hands-on training to improve adherence to a NMT program [28]. In this study, 2579 exercises were observed. In the in-person coach education group, coaches were provided with informational materials on NMT exercises. These instructional materials consisted of information on a series of NMT exercises that could be done at different skill levels (beginner, intermediate, advanced, and elite), targeting a variety of injury prevention techniques. The series could be done in 10–15 min as warm-up exercises. There was a total of 34 exercises to individualize the NMT routine for the team. The in-person education workshop was led by a certified strength and conditioning specialist, who discussed injury prevention, training, athlete performance, and nutrition. Through a practical demonstration, the coaches also received guidance on how to personalize an NMT routine for their team based on sport, age, and skill level. They were taught how to deliver exercise instructions and to provide alignment cues to correct improper techniques, and they received feedback on their delivery of the cues. A recording of the workshop was provided to the coaches afterwards for reference. In the control group, coaches received the same informational materials as the intervention group but did not participate in an in-person coach education workshop. Coaches were blinded to their own group allocation and did not know the purpose of the study. The sports teams were randomized by high school due to the possibility of contamination within a school by coach interaction [28].

We used trained data collectors unaffiliated with the teams who were hired specifically to assess coach adherence to an NMT program (including the delivery of alignment cues) at high school varsity sports teams’ practices and games 2–3 times per week. Before the start of the cluster RCT, all data collectors attended an in-person training session detailing the NMT program. During the training session, they were shown the video of the in-person coach education workshop and were provided with the same instructional materials as the coaches in order to learn the same exercises and alignment cues as the coaches.

The data collectors were instructed on the data collection forms they would be using and the corresponding exercise instructions and alignment cues for all the exercises (all are listed in Table 1). They were trained to identify the cues based on the exercise, such as posture, alignment, and position of the body. They kept track of the length of exercise done. An example of an exercise instruction is as follows for carioca: ‘Move sideways with alternating steps of your trailing foot in front of and behind your lead foot. Repeat by moving in the opposite direction’. The corresponding alignment cues are: ‘Stand up tall as you run keeping your head in line with your body. Hips, knees and toes point straight ahead as you run. See the field/court from as high as possible’. The complete list of instructions and cues can be found embedded within the data collection form found in Appendix A.

Each data collector was responsible for one or two teams per season, and they were blinded to treatment allocation (in-person coach education vs. print-only materials without hands-on coach training). The data collectors observed a practice or game 2–3 times a week for each team. At each warm-up session, they recorded in a standard structured form that asked which exercises were performed and the order in which the exercises were performed. Then, they provided either a yes or no answer to two binary questions for each exercise to determine adherence to the protocol determined pre-season for the NMT exercises: (1) Did the coach administer instructions for the exercise? (2) Did the coach administer cues to improve alignment? Next to each question, the specific
 instruction for the exercise and the alignment cues that were to be given by the coach were provided to the data collector as reference. The coaches did not have to deliver the exercise instruction or alignment cue word for word to be scored successfully, but they had to convey the general idea and correct technique as needed. The majority of athletes had to attempt the exercise following the instruction to be scored successfully. At the end of each practice or game, the data collector had to attempt the exercise following the instruction to be scored successfully, but they had to convey the exercise instructions and alignment cues given by the coaches.

For instruction cues, all of the pairs for 26 out of 29 exercises had Kappa values indicating near-perfect agreement. The remaining three exercises had substantial agreement. For alignment cues, 22 of 29 exercises had Kappa values indicating near-perfect agreement and another six had substantial agreement. The Kappa values for exercise instruction and alignment cues, with one exception, ranged from 0.63 to 1.0, indicating substantial to perfect agreement for all exercises, except for one. Several exercises had limited observations (none in one case) which limited the ability to evaluate adherence to specific exercises. However, when combining the exercises, the overall Kappa values for exercise instruction and alignment cues were 0.89 and 0.90, respectively, indicating almost perfect agreement between data collectors and independent observers, in general (see Table 1).

### DISCUSSION

Evaluation of compliance with NMT is limited by the person recording the data. If the individual is affiliated with the athletes, they are likely to be biased [26]. Moreover, there is the potential for reporting bias in that athletes or coaches who don’t respond could be less adherent in general [24]. In a meta-analysis by Sugimoto et al., looking at coach knowledge of lower limb injury prevention programs, one of the six studies reported an adherence rate of 100%, which even the author noted ‘potentially could be inaccurate’ [26]. A recent systematic review of adherence evaluated 15 studies, of which 10 (67%) used only self-reporting [27]. The remaining five studies used a combination of self-report and periodic checks by members of the study team [27]. This inconsistency and inherent bias in studies of NMT adherence must be addressed in order to develop more effective strategies to improve adherence and reduce ACL injuries.

This is the first study using data collectors and a control group of data collectors that we termed ‘independent observers’ (both unaffiliated from the team) for the measurement of adherence to NMT training to reduce ACL injury risk. In a prior systematic review of 15 studies of NMT adherence, authors relied primarily on self-report, which is a major limitation due to bias [27]. In contrast to these studies, the data collectors in our cluster RTT served as unbiased observers because unlike the team’s coaches or athletic trainers, they do not have a perceived or real conflict of interest. Additionally, a control group of independent observers were used in addition to the data collectors in order to evaluate the reliability of the measurement of adherence to the exercises.

There are some potential limitations to this study. One possible limitation is the Hawthorne effect, in which participants of a study behave differently because they know they are being observed by data collectors. However, the data collectors and independent observers were not directly part of the warm-up routine, nor interacting with the athletes, and therefore, they were unlikely to affect the coach or athlete.
behaviour. Another possible limitation is the uneven number of pairs of data collectors and independent observers per exercise due to the coaches entirely omitting certain exercises on certain days. This could also limit the potential to understand the varying Kappa values by exercise. However, by pooling the exercises to calculate overall reliability, this effect is muted when looking at the overall adherence to NMT. Lastly, there is an added cost for future compliance research using data collectors rather than the athletes or team staff and this would have to be built into the research budget.

High-inter-observer reliability was found between the independent observers and the data collectors. Although reliability was excellent overall, there were some cases where the reliability was lower for some exercises, due to small sample size and possibly by subjectivity in the measurement of adherence. Nevertheless, these results indicate that an independent data collector can provide reliable data and decrease bias associated with self-report in studies of adherence to NMT programs for sports teams.

CONCLUSION

The use of data collectors and a control group of independent observers (all unaffiliated with the teams) demonstrated excellent reliability for measuring adherence to an NMT program and should be best practice when designing implementation studies for ACL injury prevention. Future adherence studies should use unaffiliated data collectors to evaluate adherence in NMT and ACL injury prevention programs to decrease the bias associated with coach and/or team self-reporting.

FUNDING

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ETHICS APPROVAL

The study was approved by the Hospital for Special Surgery Institutional Review Board ID # 2017-0252. All participants consented to being included in the study.

DATA SHARING

Data are available upon reasonable request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsisako.2024.02.004.

References

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