

# Superior compliance with a neuromuscular training programme is associated with fewer ACL injuries and fewer acute knee injuries in female adolescent football players: secondary analysis of an RCT

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## ABSTRACT

**Background** Little is known about the influence of compliance with neuromuscular training (NMT) on the knee injury rate in football.

**Aim** To evaluate team and player compliance with an NMT programme in adolescent female football and to study the association between compliance and acute knee injury rates.

**Methods** Prospective cohort study based on a cluster randomised controlled trial on players aged 12–17 years with 184 intervention teams (2471 players) and 157 control teams (2085 players). Exposure and acute time loss knee injuries were recorded. Team and player compliance was recorded by the coaches on a player attendance form. The intervention group was divided into tertiles of compliance. Injury rates were compared by calculating rate ratios (RRs) and 95% CIs using exact Poisson tests with the low-compliance tertile as reference. Seasonal compliance trends were analysed using linear regression.

**Results** Players in the high-compliance tertile had an 88% reduction in the anterior cruciate ligament (ACL) injury rate (RR 0.12, 95% CI 0.01 to 0.85), whereas the rate in the control group players was not significantly different from those in the low-compliance tertile (RR 0.77, 95% CI 0.27 to 2.21). A significant deterioration occurred in team ( $b=-3.0\%$  per month, 95% CI  $-5.2$  to  $-0.8$ ) and player ( $b=-5.0\%$  per month, 95% CI  $-7.1$  to  $-2.9$ ) compliance over the season.

**Conclusions** Players with high compliance with the NMT programme had significantly reduced ACL injury rate compared with players with low compliance. Significant deterioration in team and player compliance occurred over the season.

## INTRODUCTION

The anterior cruciate ligament (ACL) injury rate is more than twofold higher in female football players than in their male counterparts<sup>1 2</sup> and adolescent females are especially at risk.<sup>2 3</sup> Numerous studies have evaluated the preventive effect of neuromuscular training (NMT) programmes in female football<sup>4–14</sup> and all except one<sup>5</sup> targeted adolescents. In many of these studies, the documentation of compliance with NMT has been inconsistent or incomplete and when reported compliance is usually documented by the team coach on the exposure report form.<sup>4 5 11–14</sup> Typically, the reported compliance has often been low to moderate in these studies,<sup>15</sup> but it is often unclear whether it is based on a team or individual

player level. It has, therefore, recently been suggested that both parts are essential since the overall compliance is the product of the team completion and player attendance rates.<sup>15</sup>

Of the 11 aforementioned studies, only one randomised controlled trial (RCT)<sup>14</sup> and one non-randomised controlled study<sup>10</sup> have shown significant reductions of overall or non-contact ACL injuries in female adolescent footballers with NMT. Another recent RCT has shown a significant reduction of non-contact ACL injuries in a mixed sample of female high school basketball and football players.<sup>9</sup> Besides low statistical power to break down injuries into different injury types, poor compliance is probably the other main reason why some studies show no preventive effect of their intervention.<sup>13</sup> The importance of good compliance was recently underlined in a study that evaluated the influence of team and player compliance on injury rates in female adolescent football.<sup>16</sup> In that study, teams and players were divided into compliance tertiles (high, intermediate and low). Players with high compliance had lower rates of injuries overall and acute injuries (no knee injury data reported) than players with intermediate compliance. However, when evaluated on team level, no differences in injury rates were observed between teams in the three compliance groups. It was speculated by the authors that the latter finding was due to large within-team variability in player compliance and considerable between-team variations in the exposure to football. Consequently, their findings indicate that reporting compliance exclusively on team level may be insufficient when studying the effect of NMT on injury rates.

The objectives of the present study were to evaluate both team and player compliance with an NMT programme in adolescent female football and to study the association between compliance and acute knee injury rates. Our hypothesis was that the NMT programme would have a greater preventive effect in teams and players with higher compliance than those with lower compliance.

## MATERIALS AND METHODS

This is a substudy of a cluster RCT that evaluated the preventive effect of a 15 min NMT programme (Knäkontroll, SISU Idrottsböcker, Sweden, 2005) on acute knee injuries in female adolescent football players.<sup>14</sup> The study design, the NMT programme and the main results of the RCT have been reported previously.<sup>14 17</sup>

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## Study procedures

Briefly, teams with **players aged 12–17 years** in eight Swedish districts were recruited. Data were collected during the competitive season (1 April–31 October 2009). Individual playing time for each training session and match was registered by the coach on a computer-based player attendance form.<sup>18 19</sup> Study-designated physiotherapists (n=68) and physicians (n=8) served as medical support to the teams and assisted coaches with data collection and injury evaluation. A recordable acute knee injury was defined as an injury that had a sudden onset and led to a player being unable to fully participate in future training or match play (contusions excluded).<sup>14 17</sup> ACL injury was defined as a first time or recurrent partial or total rupture of the ligament either isolated or associated with concomitant injuries to the knee joint.<sup>20</sup>

## Intervention

At a prestudy meeting, a study therapist gave practical instructions of the NMT programme to one coach and one player from each intervention group team. Intervention team coaches also received a CD-ROM and a leaflet describing the exercises and were instructed to complete the NMT programme during the warm-up at two training sessions/week.

## Team and player compliance

For each training session, coaches documented whether the team completed the NMT programme (yes/no), as well as individual player participation on the player attendance form. This documentation enabled evaluation of team and individual player compliance.<sup>15 16</sup> To monitor the accuracy of the coach-reported compliance, study therapists were instructed to make two unannounced visits to each intervention team during the season; one during the first part (spring) and the other during the second part (autumn). At the start of the season, coaches provided study therapists with a preliminary training schedule specifying the two weekly sessions during which the NMT programme was intended to be carried out. The study therapists were instructed to observe the beginning of the training session out of sight for the onfield coach and document the execution of the NMT programme (yes/no). Control group teams were instructed to carry out their usual training throughout the season and none reported performing any NMT similar to the intervention programme at study inclusion.

## Statistical methods

The primary outcome was ACL injury rate and the secondary outcomes were rates of any acute knee injury and severe knee injury (>4 weeks absence).<sup>14 17</sup> Descriptive continuous data for compliance are presented as mean with SD and range. The rate of completed NMT programmes recorded during the study therapists' unannounced visits are presented as a proportion of the total number of eligible visits. Injury rates are presented as the number of injuries per 1000 h of exposure with 95% CIs.

Using a similar approach employed in two previous studies,<sup>16 21</sup> teams and players (independent of team compliance) in the intervention group were stratified into tertiles of compliance (low, intermediate and high) based on their mean number of weekly NMT sessions during the season. For players who incurred an acute knee injury or were censored (leaving the team for reasons other than acute knee injury), the mean number of weekly NMT sessions until injury or censoring were calculated in the player stratification. To enable stratification into the compliance groups, exposure and injury data were included starting from each team's and player's first NMT session during the study

period (eg, if a team started registration on 1 April and had their first NMT session on 8 April, data were included from 8 April and onwards). For the current analyses, this resulted in exclusion, from the original RCT's intervention group,<sup>14</sup> of eight players, 3921 training-hours, 1427 match-hours and two acute knee injuries (1 patella subluxation and 1 lateral collateral ligament sprain).

Seasonal trend for team and player compliance with the NMT programme was analysed using linear regression with team compliance or player compliance (proportion of completed NMT programmes of total team and player training sessions, respectively) as dependent variable and month and compliance tertile as independent variables. The same approach was used to analyse seasonal trends for player training attendance rates (percentage of players attending training).

Injury rates in the groups were compared by calculating rate ratios and corresponding CIs using exact Poisson tests according to Blaker.<sup>22</sup> For the outcomes acute knee injury and severe knee injury, adjustment for age, menarche, match frequency and district (stratification factor) was performed using Poisson regression. Owing to the small number of events, adjustment for these factors was not possible for the primary outcome (ACL injury). Possible cluster effects for club belonging were not considered in the analyses due to negligible intraclass correlations for all outcomes (ACL injury −0.0026, severe knee injury −0.0003 and acute knee injury 0.0070).

All tests were two-sided with a significance level of  $p < 0.05$ . Analyses were performed using R (V2.15.0 R Foundation for Statistical Computing, Vienna, Austria).

## RESULTS

This substudy comprised 184 teams (121 clubs) with 2471 players in the intervention group and 157 teams (109 clubs) with 2085 players in the control group. **In total, 47 acute knee injuries in 46 players (7 ACL injuries in 7 players) in the intervention group and 47 acute knee injuries in 44 players (14 ACL injuries in 14 players) in the control group were included.** Player attendance at training sessions was 71% in both groups.

## Team compliance

The intervention group teams completed the NMT programme in 5244 (79%) of the 6632 team training sessions, or as a mean 1.4 NMT sessions/week (table 1). Teams in the low-compliance, intermediate-compliance and high-compliance tertiles completed the NMT programme in 63%, 82% and 89% of team training sessions, respectively. Overall, a significant deterioration in compliance over the season ( $b = -3.0\%$  per month, 95% CI  $-5.2$  to  $-0.8$ ;  $p = 0.010$ ) was observed. This was more pronounced in the low-compliance tertile, while the trend in the high-compliance tertile remained fairly stable (figure 1).

## Player compliance

Intervention group players completed, on average, 21 NMT sessions over the season, equivalent to 1 session/week (table 1). A significant deterioration in player compliance over the season ( $b = -5.0\%$  per month, 95% CI  $-7.1$  to  $-2.9$ ;  $p < 0.001$ ) was observed (figure 2). Similarly, player attendance at training sessions deteriorated over the season ( $b = -2.0\%$  per month, 95% CI  $-3.1$  to  $-0.9$ ;  $p = 0.001$ ), specifically in the intermediate-compliance (from 81% to 69%) and low-compliance tertiles (from 70% to 41%), while attendance rates in the high-compliance tertile remained more stable (from 91% to 86%; figure 3).

**Table 1** Intervention group team and player exposure and compliance data overall and stratified into high (n=61 teams, 831 players), intermediate (n=60 teams, 823 players) and low (n=63 teams, 817 players) compliance tertiles

	Teams	Players
Mean number of training sessions during season (SD, range)	38 (12, 5–77)	28 (13, 1–76)
Low compliance	35 (13, 5–71)	20 (11, 1–64)
Intermediate compliance	39 (10, 20–66)	28 (10, 1–69)
High compliance	41 (13, 8–77)	36 (12, 3–76)
Mean number of matches during season (SD, range)	19 (8, 1–50)	16 (8, 0–56)*
Low compliance	18 (7, 1–41)	13 (8, 0–41)
Intermediate compliance	20 (7, 5–42)	16 (7, 0–40)
High compliance	20 (9, 3–50)	18 (9, 0–56)
Mean number of neuromuscular training (NMT) sessions during season (SD, range)	30 (10, 1–52)	21 (10, 1–51)
Low compliance	22 (8, 1–36)	12 (5, 1–26)
Intermediate compliance	32 (6, 17–48)	22 (6, 1–37)
High compliance	37 (10, 8–52)	30 (9, 2–51)
Mean number of NMT sessions/week (SD, range)	1.4 (0.3, 0.3–2.0)	1.0 (0.4, 0.0–2.1)
Low compliance	1.1 (0.2, 0.3–1.3)	0.6 (0.2, 0.0–0.9)
Intermediate compliance	1.4 (0.1, 1.3–1.6)	1.0 (0.1, 0.9–1.2)
High compliance	1.7 (0.1, 1.6–2.0)	1.4 (0.2, 1.2–2.1)

\*Maximum number of player matches during season exceeds number of team matches because of matches played with other teams.

### Compliance monitoring by study therapists

Of the 368 planned unannounced visits (184 teams × 2 visits), 321 (87%) could be evaluated regarding compliance with the NMT programme (47 sessions could not be evaluated due to team dropout during the study or cancellation of the training session). The study therapists completed 284 (88%) of the eligible visits and the NMT programme was initiated in 255 (90%) of these sessions. Crossmatching of study therapists' forms with the coach report in the player attendance record showed identical registrations in 279 (98%) of the visited training sessions; in five training sessions coaches had registered completion of the NMT programme but the study therapists reported no NMT during their visit.

### Injury rates

At team compliance level, no significant differences in injury rates for any outcome were found between the low-compliance tertile and the intermediate-compliance or high-compliance tertiles or the control group (table 2). At player compliance level, the players in the high-compliance tertile had an 88% reduction in the ACL injury rate compared with the low-compliance tertile (table 2). Consistently, the intermediate-compliance and high-compliance tertiles had rate reductions between 72% and 90% for severe knee injuries and acute knee injuries compared with the low-compliance tertile. The adjusted analyses for the secondary outcomes gave similar results (data not shown). Similar or lower injury rates were seen in the control group compared with the low-compliance tertile at player compliance level.

### DISCUSSION

The principal finding in this study was that players with high compliance with the NMT programme had significantly reduced

rates of ACL injury, severe knee injury and any acute knee injury compared with players with low compliance. Players in the low-compliance tertile had no protective effect at all, showing similar or even higher injury rates than the control group performing no NMT programme. Additionally, significant deteriorations were seen in team and player compliance over the season.

### Knee injury prevention

The current study extends the recent literature that high compliance is a key factor in yielding significant reductions of ACL injuries with NMT programmes.<sup>15</sup> In the main cluster RCT, we reported a 64% lower overall ACL injury rate in the intervention group compared with the control group.<sup>14</sup> In this substudy, the teams and players of the intervention group were categorised into compliance tertiles similar to the procedure in other recent studies.<sup>16–21</sup> Players in the high-compliance tertile had an 88% lower ACL injury rate compared with those in the low-compliance tertile. Additionally, and probably equally important, the ACL injury rate for players in the low-compliance tertile was not significantly different from that in the control group.

Significant reductions in the rates of severe knee injury and any acute knee injury ranging from 72% to 90% were also seen in the intermediate-compliance and high-compliance tertiles compared with the low-compliance tertile. Although data on knee injuries were not reported in two previous similar studies evaluating the association between compliance with NMT and injury rates in female youth football,<sup>16–21</sup> these two studies, consistent with our findings, reported the greatest preventive effect in the highest compliance tertile. Worth noting is that players in the low-compliance tertile in the current study had higher injury rates than the control group players. A possible explanation is that low-compliant players represent a sample of players with low motivation to physically prepare for sports and/or participated in teams in which the coach had lesser interest in preventive training, which could lead to increased injury rates.

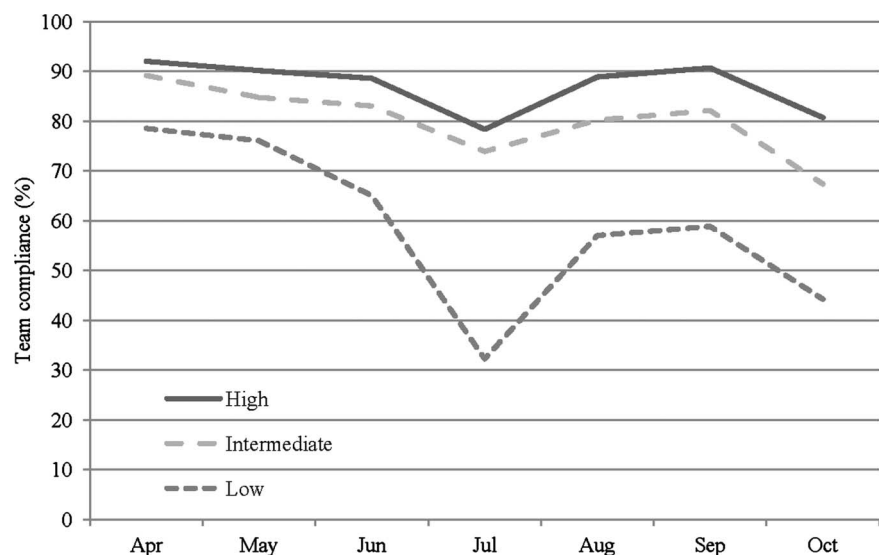
In agreement with a previous similar trial,<sup>16</sup> no significant differences were seen in injury rates between teams belonging to the high-compliance, intermediate-compliance and the low-compliance tertiles. This probably reflects a low player attendance at training sessions, and thus also to NMT sessions, in some teams in the high-compliance and intermediate-compliance tertiles. It further highlights the importance of monitoring compliance at a player level in addition to team compliance.

### Compliance and monitoring

The teams reported carrying out the NMT programme at 79% of all training sessions, which is similar to the rates reported in previous trials in youth football (77–86%).<sup>16–21</sup> Delivery of the NMT programme to intervention group coaches included a pre-study instructional meeting, where a trained physiotherapist instructed coaches on proper exercise technique and on how to progress the players through the programme. Coaches also received a free CD-ROM and leaflet with exercise instructions. Interestingly, Steffen *et al*<sup>21</sup> recently concluded that such an approach was more effective in terms of increasing team compliance with a similar NMT programme (Fédération Internationale de Football Association (FIFA) 11+) compared with a web-based only delivery. No additional benefits were seen in the subgroup that in addition to a preseason coach workshop also had regular follow-ups by a physiotherapist at their training sessions.<sup>21</sup>

## Original article

**Figure 1** Team compliance with the neuromuscular training (NMT) programme in the high-compliance, intermediate-compliance and low-compliance tertiles of the intervention group over the season. Compliance is reported as the percentage of the total number of training sessions where the NMT programme was carried out each month (number of team NMT sessions/number of team training sessions $\times 100$ ). The low compliance in July is due to mid-season summer break from training and matches.



Despite the relatively high compliance with the NMT programme in the current study, team as well as player compliance deteriorated over the season, and this decrease was most pronounced in the low-compliance tertile. This tallies with recently published data from Norwegian girls' football that teams performed fewer NMT sessions in the second half of the season compared with the first half, with the decrease being most prominent in teams with the lowest compliance.<sup>16</sup> This deterioration could reflect decreasing motivation among coaches to use the NMT programme throughout an entire season, although it should be noted that team compliance in the high-compliance and intermediate-compliance tertiles was fairly consistent over the whole season. There is thus a need for further evaluation of motivational barriers and facilitators among coaches to ensure high compliance with this NMT programme over the entire season. Additionally, the decrease in player compliance in the later stages of the season also reflects a deterioration of player attendance at training sessions over the season. A similar decrease in player attendance rates was recently reported in a study on community Australian footballers,<sup>23</sup> stressing the importance of encouraging players to attend formal training sessions in order to increase the reach of exercise interventions throughout the season.

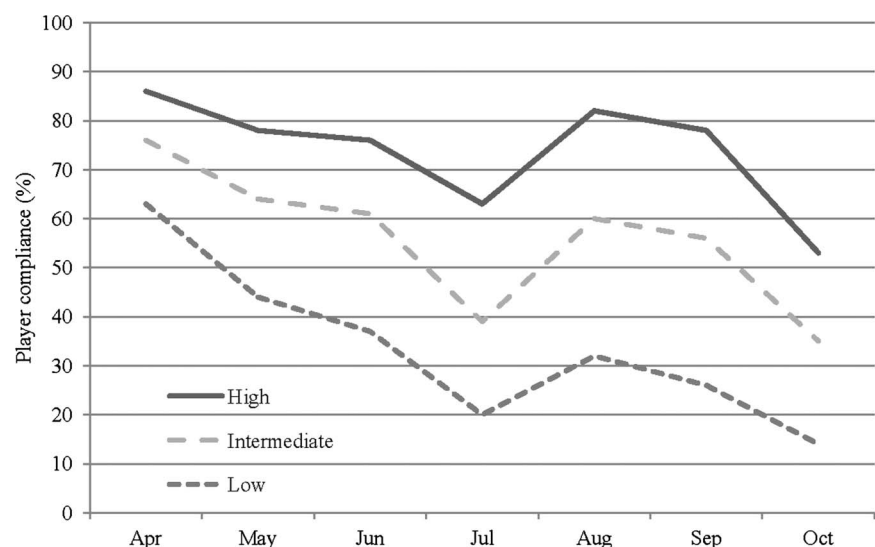
The accuracy of the coach-reported compliance was monitored via unannounced visits by the study therapists,<sup>17</sup> an approach later also used by others.<sup>21</sup> Identical reports were found in 98% of cases indicating that the coach-reported compliance was reliable. In the other study in a similar setting, 85% of the NMT sessions were correctly reported.<sup>21</sup>

### Strengths and limitations

The current substudy has several strengths. For example, it utilised a previously established approach in stratifying the intervention group into tertiles of compliance.<sup>16 21</sup> Moreover, compliance was evaluated from both team and player perspectives, which is essential since the overall compliance is dependent on team completion of the NMT programme and attendance rates.<sup>15</sup> Additionally, the large sample with more than 4500 players makes our study the first to evaluate the influence of compliance on knee injury rates specifically, which has not been possible in previous smaller studies.<sup>16 21</sup>

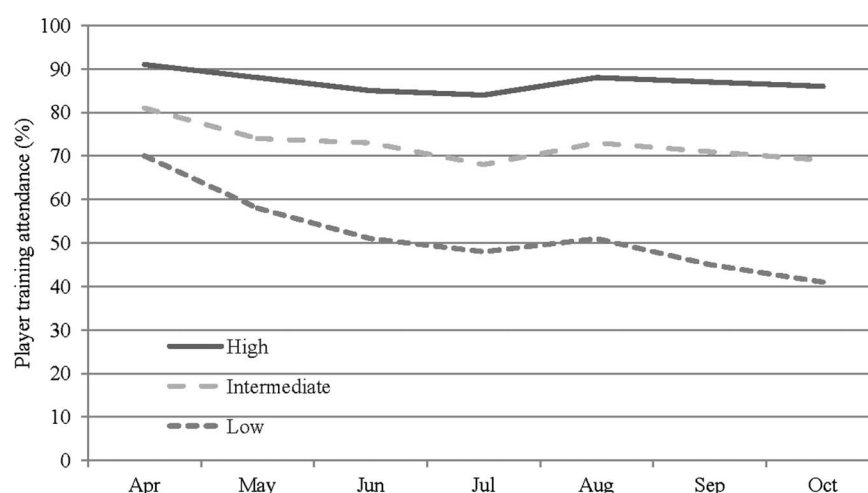
This study also has a few important limitations. First, players were divided into compliance tertiles based on their weekly NMT session rate. This means that players who were injured early in the season may have been stratified into the intermediate-compliance or high-compliance tertiles based on a

**Figure 2** Player compliance with the neuromuscular training (NMT) programme in the high-compliance, intermediate-compliance and low-compliance tertiles of the intervention group over the season. Compliance is reported as the percentage of the total number of training sessions where the NMT programme was carried out each month (number of player NMT sessions/number of total player training sessions $\times 100$ ). The low compliance in July is due to mid-season summer break from training and matches.





**Figure 3** Player training attendance rates in the high-compliance, intermediate-compliance and low-compliance tertiles of the intervention group over the season.



high weekly rate of NMT sessions up until the injury event, but in effect having carried out only few actual NMT sessions. It can be argued that a preventive effect of NMT on acute knee injuries can only be seen after completion of up to a certain (unknown) number of sessions, making our method of stratification into compliance tertiles less valid. However, if anything, this will only have underestimated the preventive effect of being in the intermediate-compliance to high-compliance tertiles. Second, owing to the small number of ACL injuries it was not possible to compute adjusted rate ratios for the primary outcome. Consequently, only crude rate ratios are reported, which is similar to a previous study by Soligard *et al.*<sup>16</sup> However, adjustment was possible for acute and severe knee injuries and this analysis showed almost identical findings as the crude analysis. Third, training sessions in the control group were not monitored and although none of the control group coaches reported performing any NMT programme at study inclusion, we were not able to register possible contamination of the NMT intervention in the control group over the season.

### Implications

This study shows that effective prevention of acute knee injury is associated with high individual player compliance to NMT.

Preventive measures are more likely to be effective when the intervention does not rely on an individual's behaviour modification,<sup>24</sup> and by implementing NMT as a routine warm-up this will become an integrated part of football training and increase player compliance. Importantly, high player attendance at training sessions is also needed to achieve high player compliance.<sup>23</sup> It is obvious that the coach is a key person in preventing knee injuries in female adolescent football players. Given the growing body of evidence that NMT programmes can effectively prevent lower limb injuries in adolescent athletes,<sup>8–10 12 14 21</sup> it is essential to translate this knowledge to various stakeholders in youth sports. A recent study reported knowledge gaps in injury prevention among football coaches, adolescent players and parents, and the current evidence,<sup>25</sup> showing that much work is still required. Finally, having the knowledge of effective preventive measures does not guarantee a change in behaviour,<sup>24</sup> and

**Table 2** Injury rates among teams and players stratified into high (n=61 teams, 831 players), intermediate (n=60 teams, 823 players) and low (n=63 teams, 817 players) compliance tertiles of the intervention group and the control group (n=157 teams, 2085 players)

	Teams			Players		
	Number of injuries	Injury rate*	Rate ratio (95% CI)	Number of injuries	Injury rate*	Rate ratio (95% CI)
<b>Anterior cruciate ligament injury</b>						
Low compliance	3	0.07	1 (reference)	5	0.14	1 (reference)
Intermediate compliance	3	0.06	0.90 (0.16 to 4.96)	1	0.02	0.15 (0.01 to 1.07)
High compliance	1	0.02	0.28 (0.01 to 2.58)	1	0.02	0.12 (0.01 to 0.85)
Control	14	0.11	1.58 (0.48 to 6.46)	14	0.11	0.77 (0.27 to 2.21)
<b>Severe knee injury</b>						
Low compliance	7	0.16	1 (reference)	17	0.48	1 (reference)
Intermediate compliance	12	0.25	1.54 (0.57 to 4.44)	4	0.08	0.17 (0.05 to 0.49)
High compliance	5	0.10	0.61 (0.19 to 2.05)	3	0.05	0.10 (0.03 to 0.34)
Control	31	0.24	1.51 (0.67 to 3.72)	31	0.24	0.50 (0.27 to 0.95)
<b>Any acute knee injury</b>						
Low compliance	15	0.32	1 (reference)	26	0.72	1 (reference)
Intermediate compliance	15	0.33	1.03 (0.47 to 2.15)	9	0.19	0.26 (0.12 to 0.57)
High compliance	16	0.31	0.98 (0.45 to 2.05)	12	0.20	0.28 (0.13 to 0.55)
Control	47	0.34	1.07 (0.58 to 2.07)	47	0.34	0.48 (0.29 to 0.82)

\*Injury rate is expressed as number of injuries/1000 h.

## Original article

studies evaluating intervention delivery and identifying motivators and barriers (among various sports stakeholders) to adopt and maintain NMT programmes over time are warranted. Such future evaluations could preferably be conducted using frameworks established for team sports, such as the **RE-AIM Sports Setting Matrix**.<sup>26</sup>

## What are the new findings?

- Female adolescent football players with high compliance with a 15 min warm-up neuromuscular training (NMT) programme had significantly reduced rates of ACL injury, severe knee injury and any acute knee injury compared with players with low compliance.
- Players with low compliance with the NMT programme had similar or even higher knee injury rates than players in the control group receiving no intervention.
- Significant deteriorations were seen in both team and player compliance over the season.
- Coach reporting seems to be a reliable method to capture compliance with an NMT programme, with 98% of sessions having matched records between the coach and the unannounced visits by a study designated physiotherapist.

## How might it impact on clinical practice?

Considering the low training frequency and relatively low player attendance at training in youth female football teams, it is recommended that the NMT programme is implemented as a routine at all training sessions with the team to increase the reach among players. By monitoring attendance at training sessions and completion of NMT among the players, coaches can ensure that players have sufficient compliance with NMT to gain a preventive effect. Coaches should also consider recommending players with low training attendance to carry out additional NMT training at home.

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**Contributors** MH, IA and MW were responsible for the conception and design of the study. MH and MW coordinated the study, managed all aspects including data collection and wrote the first draft of the manuscript, which was critically revised by IA and PW. PW conducted the analyses, which were planned and checked with the coauthors. All authors contributed to the interpretation of findings and had full access to all data and approved the final version of the manuscript. MH and MW are the guarantors.

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**Competing interests** MH and MW constituted the medical staff of the male under-19 national team of the Swedish FA between 2007 and 2011.

**Patient consent** Obtained.

**Ethics approval** The study was approved by the regional ethical review board in Linköping (# M197-08).

**Provenance and peer review** Not commissioned; externally peer reviewed.

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# Superior compliance with a neuromuscular training programme is associated with fewer ACL injuries and fewer acute knee injuries in female adolescent football players: secondary analysis of an RCT

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