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Original Research

Could specific exercises based on a movement screen prevent injuries in adolescent elite athletes?

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ABSTRACT

Objectives: The primary aim of this study was to explore if specific exercises based on the nine test screening battery (9SB) reduce short-term and seasonal injury occurrence in adolescent elite athletes.
Setting: Youth elite sports.
Design: Prospective intervention study over 1-year.
Participants: Adolescent elite athletes (n = 216) in age 15–20 from seven different sports.
Main outcome measures: Seasonal/short-term injury incidence and seasonal substantial/injury prevalence was obtained via weekly surveys completed by study participants.
Results: There was a significant ($p = 0.036$) difference in the seasonal substantial injury prevalence across number of times the exercises were performed (exercise category), where athletes performing the exercises ≥4 times/week reported significantly ($p = 0.048$) higher seasonal substantial injury prevalence compared to athletes completing the exercises once a week (median 15.4 vs 0%, $r = 0.25$). No statistically significant difference in injury incidence ($p = 0.429$) or seasonal injury prevalence ($p = 0.171$) was found across exercise category. Performing the exercises once a day compared to not at all did not reduce the short-term risk of new injury or substantial injury.
Conclusions: Our results provide supporting evidence that completing specific exercises based on the 9SB have no group effect on short-term or seasonal injury occurrence in adolescent elite athletes.

1. Introduction

The injury risk is high in young elite athletes in both individual and team sports (Kolt & Kirkby, 1999; Le Gall et al., 2006; Westin, Alricsson, & Werner, 2012). For instance, in handball and athletics an injury incidence of six and four injuries per 1000 h of exposure to sports has been identified, respectively (Jacobsson et al., 2013; Moller, Attermann, Myklebust, & Wedderkopp, 2012). The majority of randomised controlled trials have implemented training programs to decrease injury risk in sports, targeting e.g. balance, strength or neuromuscular control, as warm-up programs or as separate training sessions (Herman, Barton, Malliaras, & Morrissey, 2012; Hewett, Ford, & Myer, 2006; Leppanen, Aaltonen, Parkkari, Heinonen, & Kujala, 2014). These programs have been successful in reducing injury numbers in mainly team sports (Emery, Roy, Whittaker, Nettel-Aguirre, & van Mechelen, 2015; Lauersen, Bertelsen, & Andersen, 2013). For instance, improving landing techniques have been found to be effective in preventing lower extremity injuries (Aerts, Cumps, Verhagen, Verschueren, & Meeusen, 2013). However, most injury prevention programs have included adult elite athletes instead of younger athletes (McBain et al., 2012), resulting in lack of effective strategies to prevent injuries in young elite athletes. Further on, these programs are not individually based, instead designed for a certain population or sport, compromising the overall effectiveness.

Traditionally, implementing specific training programs to target muscular strength, flexibility or neuromuscular control, are a commonly used strategy to prevent injuries in young athletes (Al Attar, Soomro, Pappas, Sinclair, & Sanders, 2016; Emery et al., 2015; Hübscher et al., 2010; LaBella et al., 2011; Longo et al., 2012; Soligard et al., 2008; van Beijsterveldt et al., 2012). Even if these programs have been showed to be successful (Al Attar et al., 2016; Hübscher et al., 2010), none of these are individual based, which may reduce their overall effectiveness. For instance, all athletes may not need to improve neuromuscular control during a squat exercise, leading to waste of time and ineffective preventive

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measures.

Movement screening tests, aiming to identify deficits in strength, flexibility or neuromuscular control, have been suggested to identify athletes at risk for injury (Cook, Burton, & Hoogenboom, 2006). These tests are reliable, low costly, individual based and could be administered on-field or in clinical settings (Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2012; Leeder, Horsley, & Herrington, 2016). However, researchers have questioned the use of screening for movement quality to reduce injury risk in sports (Dorrel, Long, Shaffer, & Myer, 2015; Moran, Schneiders, Mason, & Sullivan, 2017) or in the military (Whittaker et al., 2017). The nine test screening battery (9SB) is a movement test, recently developed from the Functional Movement Screen (Cook et al., 2006). Orginally, it consisted of nine functional and complex movement tests, aiming to address non-functional movement patterns, asymmetries or mobility deficits (Frohm et al., 2012). Two tests were recently added, resulting in that the latest version of the 9SB consists of eleven different movement tests, distinguished from the seven movement tests of the Functional Movement Screen. The screening test is used to identify intrinsic risk factors. By modifying these risk factors, such as implementing training protocols, it is suggested that injury occurrence may be prevented. However, even if the 9TSB has been found to be reliable, both for interrater (ICC: 0.68–0.80) and intrarater (ICC: 0.75) reliability (Frohm et al., 2012), two recent studies demonstrated no association between total score and lower extremity injury in football players (Bakken et al., 2017) or orienteerers (Leandersson, Heijne, Flodstrom, Frohm, & von Rosen, 2018). Yet, no study has tested the effectiveness of using an intervention program consisting of specific exercises based on findings from a movement screen to reduce injury incidence.

Prescribing individually exercises based on the 9SB is given to correct faulty movement patterns and asymmetries in athletes assessed as having non-functional movement patterns. For instance, athletes with compensatory movements, such as a basketball player landing in a knee valgus position, could be given specific exercises to change landing technique, whereas another athlete could work on improving neuromuscular control of the ankle joint, and thereby reduce the risk of ankle sprains. This may enhance the effectiveness and adherence to such programs, since the exercises prescribed is individually based. However, there is lack of data on the effect of specific exercises based on movement screens in reducing number of injuries in young elite athletes. The primary aim of this study was therefore to explore if specific exercises based on the 9SB reduce short-term and seasonal injury occurrence in adolescent elite athletes. Our hypothesis was that performing the specific exercises based on the 9SB is associated with reduced seasonal injury occurrence.

2. Method

This study is part of the larger KASIP-study (Karolinska Athlete Screening Injury Prevention) project, which aims to understand injury occurrence and associated risk factors in Swedish adolescent elite athletes. Ethical approval has been received from the Regional Ethical Committee in Sweden (2011/749–31/3).

2.1. Data collection and sample

Adolescent elite athletes from fourteen National Sports High Schools were invited to participate in an injury surveillance and intervention study. The athletes of the contacted schools participate in sports such as athletics, cross-country skiing, downhill-skiing, freestyle, handball, orienteering and ski-orienteering. To attend these schools, athletes need to be among the top in terms of ranking in their age group for respective sporting events. Therefore adolescent athletes studying at National Sports High Schools are defined as elite athletes.

The total sample of athletes ($n = 365$) were subsequently invited by e-mail between September and December 2014 to participate in the study, of which 278 athletes (76.2%) responded to the call. A bi-weekly questionnaire was e-mailed to athletes over a period of 52 weeks. In the case of nonresponse, a reminder e-mail was sent four days later to ask about the preceding week. The software Questback online survey (Questback V. 9.9, Questback AS, Oslo, Norway) was used for data collection. To be included in data analysis, athletes needed to have reported at least 10% (>2 questionnaires) of all weekly questionnaires, completed the 9SB and given specific exercises. This resulted in that 62 athletes were excluded ($n = 34 \leq 2$ questionnaires, $n = 27$ did not complete the 9SB, $n = 1$ was not given specific exercises due to having top score on 9SB). The excluded cohort did not differ from the main cohort with respect to current injury ($p = 0.962$), history of previous injury ($p = 0.457$) or sex ($p = 0.158$). The final sample consisted of 216 adolescent elite athletes (female 50%) in age 15–20, participating in athletics ($n = 71$), cross-country skiing ($n = 54$), downhill-skiing ($n = 6$), freestyle ($n = 5$), handball ($n = 25$), orienteering ($n = 50$) and ski-orienteering ($n = 5$).

2.2. Nine plus screening battery

The 9SB, described in detailed by Frohm et al. (Frohm et al., 2012), aims to analyse the quality of functional movement patterns, originally during nine different tests (deep squat, one-legged squat, in-line lunge, active hip flexion, straight leg raise, push up, diagonal lift, seated rotation, functional shoulder mobility), with two tests recently added (deep one-legged squat, drop jump). The test is reliable, both for inter- (ICC: 0.75) and intra-rater (ICC: 0.80) reliability (Frohm et al., 2012). The quality of the performance is assessed and compensatory movements, strength or mobility deficits are identified according to strict criteria. After the screening, each athlete was instructed to perform two to three exercises to improve movement pattern based on findings from the 9SB. For instance, an athlete with increased knee valgus motion during the deep squat test may work on improving knee control motion through squat and jumping exercises. Another athlete may target the flexibility of hamstrings or quadriceps muscles based on findings from the straight leg raise or in-line lunge test.

In this study, the test assessors consisted of physiotherapists with several years of clinical experience of the 9SB. The physiotherapists were in charge of prescribing the most suited exercises based on findings of the 9SB and had no lists of specific exercises to choose from. However, exercises prescription is part of the education in 9SB that all physiotherapists had completed, likely resulting in that similar selection of exercises are given, from two different physiotherapists, to correct a specific movement impairment. In average, the athletes were asked to perform two to three exercises at least three times a week, depending on the purpose of the exercises (e.g. improving mobility, strength, neuromuscular control etc.).

2.3. Questionnaire

The valid version of the OSTRC (*Oslo Sports Trauma Research Centre*) Overuse Injury Questionnaire (Clarsen, Myklebust, & Bahr, 2013) and questions about new injury and return to sport, as described by Jacobsson et al. (Jacobsson et al., 2013) were used to collect injury data. However, in this specific report, only data from the OSTRC (*Oslo Sports Trauma Research Centre*) Overuse Injury Questionnaire were analysed. The OSTRC Overuse Injury

Questionnaire addresses injury consequences on sports participation, performance, training and pain, with each prompted in a single question with multiple-choice options. The athletes also self-reported how often they had performed the exercises based on a single question with multiple-choice options ("0 times/week", "once a week" "2–3 times/week", "4-5times/week"," ≥6 times/week"). It took approximately 5 min to complete the questionnaire and the average response rate over the 52 weeks was 59%.

2.4. Operational injury definitions

All injury data were self-reported. An injury was defined as any physical complaint that affected participation in normal training or competition, led to reduced training volume, experience of pain or reduced performance in sports. A substantial injury was defined as an injury leading to moderate or severe reductions in either training volume, performance, or complete inability to participate in sports. A new injury was identified as any new physical complaint resulting in reduced training volume, experience of pain, difficulties participating in normal training or competition, or reduced performance in sports. Consequently, the injury definitions incorporate both acute and overuse injuries.

2.5. Data analysis

The median number of times the athlete performed the exercises over 52 weeks was used to construct the exercise group category ("≥4 times/week", "2-3times/week", "Once a week", "Not performing the exercises"). The substantial injury prevalence measure was determined for each athlete by dividing the number of times the athlete reported substantial injury with the number of questionnaire responses. A similar calculation was conducted for the athletes reporting prevalence of injury or new injury. The seasonal injury prevalence, substantial injury prevalence measure and injury incidence were calculated by taking the average bi-weekly substantial injury prevalence and injury incidence, respectively, over the 52 weeks.

Due to the non-normally distributed (positively skewed) nature of seasonal injury/substantial injury prevalence and injury incidence, as assessed by Shapiro-Wilk's test ($p > 0.05$), a Kruskal-Wallis H test, followed by pairwise comparison with the Bonferroni correction, was conducted to explore differences in injury data across exercise category. Effect sizes (r) for significant differences were calculated. The risk of reporting substantial injury or new injury the current two weeks the exercises were completed or the subsequent two weeks after the exercises had been performed, was determined. For these analyses only injury free athletes the previous time-point, and thereby at risk of injury, were included. In case of being injured, the athlete was left censored until reporting to be injury free. Relative risk (RR) measures were calculated. All analyses were performed using the SPSS software for Windows, version 24.0 (SPSS, Evanston, IL), with the level of significance set at a p-value ≤0.05 for all tests.

3. Results

The median value for the number of times the athletes (n = 216) performed the exercises was once a week and every fifth athlete (n = 44) did not perform the exercises the majority of reporting times (Table 1). No significant differences in reporting serious injury at study start (p = 0.218) or history of previous injury the last year (p = 0.470) were found across exercise category. The proportion of athletes not completing the exercises or completing the exercises once a week increased along the study course (Fig. 1). In the last ten weeks of the study, 35% (n = 76) of the athletes did not do the exercises, 31% (n = 67) completed the exercises once a week, whereas 13% (n = 28) performed the exercises at least four times a week.

3.1. Association between injury and exercise category

There was a significant (p = 0.036) difference in the seasonal substantial injury prevalence across exercise category (Table 2). Pairwise comparisons revealed that the athletes performing the exercises ≥4 times/week reported significantly (p = 0.048) higher seasonal substantial injury prevalence compared to the athletes completing the exercises once a week (median 15.4 vs 0%, r = 0.25) (Fig. 2). No statistically significant difference in injury incidence (p = 0.429) or seasonal injury prevalence (p = 0.171) was found across exercise category.

3.2. The relation of exercise category and injury risk the current and subsequent two weeks

A reversed u-shaped association between injury incidence the

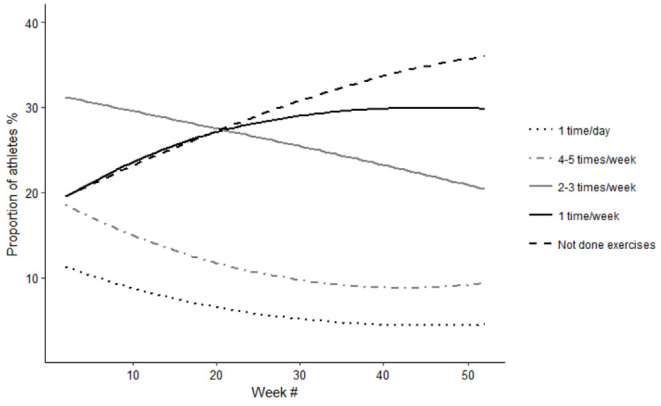

Fig. 1. Number of times the exercises were performed along the 52 weeks (loess fit).

Table 1
Demographics of athletes based on exercise category.

	≥4 times/week	2-3 times/week	Once a week	Not done exercises
Number of athletes (%)	28 (13.0)	70 (32.4)	74 (34.3)	44 (20.4)
Number of females/males (%)	13/15 (46.4/53.6)	36/34 (51.4/48.6)	33/41 (44.6/55.4)	26/18 (59.1/40.9)
Age[a]	16 (16–19)	17 (15–19)	17 (16–20)	16.5 (15–19)
Serious injury at study start, n (%)[b]	7 (25.0)	13 (18.6)	7 (9.5)	7 (15.9)
History of injury[c], n (%)[d]	10 (38.5)	18 (28.6)	16 (25.0)	14 (36.8)

[a] Median (range).
[b] Pearson's chi-squared, p = 0.218.
[c] Sustained an injury during the last year that partly or completely hindered training for a continuous period of at least three weeks in a row.
[d] Pearson's chi-squared, p = 0.470.

Table 2
Injury incidence and seasonal injury/substantial injury prevalence over the 52 weeks, by exercise category. Presented by median values (25–75th percentiles).

	≥4 times/week	2-3 times/week	1 time/week	Not done exercises	p-value
Injury incidence (%)	4.7 (0–7.7)	0 (0–7.7)	0 (0–7.7)	0 (0–7.0)	0.429
Seasonal injury prevalence (%)	32.1 (10.3–55.0)	25.0 (6.7–53.8)	17.4 (7.7–37.5)	31.8 (10.1–62.7)	0.171
Seasonal substantial injury prevalence (%)	15.4 (3.1–27.4)	6.5 (0–30.8)	0 (0–15.4)	4.1 (0–22.9)	0.036

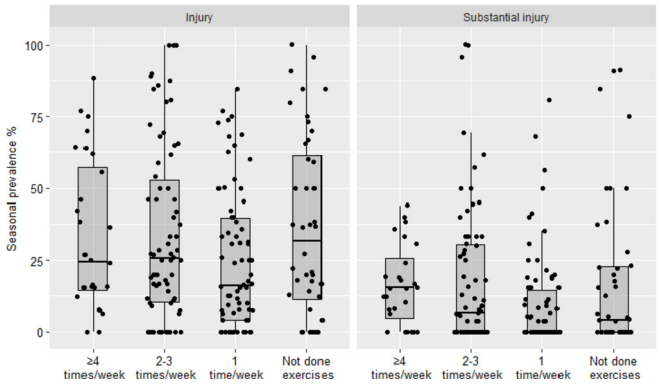

Fig. 2. Seasonal injury and substantial injury prevalence by the median number of times performing the exercises.

subsequent two weeks and exercise category was observed (Fig. 3), where athletes completing the exercises two or three times per week had the highest injury risk (RR 1.3–1.7). The risk of reporting new injury the same 2 weeks as the exercises were completed differed slightly across exercise category with the greatest difference occurring between athletes completing exercises four to five times a week compared to athletes not doing the exercises at all (RR 1.2).

A linear decreasing trend was detected between the risk of reporting substantial injury the subsequent two weeks and exercise category (Fig. 4), where athletes completing the exercises once a day had the highest injury risk (RR 1.1–1.8). Athletes performing the exercises more than four times a week reported the highest risk of substantial injury the current two weeks (RR 1.4–1.9).

4. Discussion

Our results provide supporting evidence that completing specific exercises based on the 9SB do not decrease the short-term or the seasonal injury occurrence in adolescent elite athletes. More specifically, we found that completing the exercises more than four times a week was associated with a higher seasonal injury risk and risk of substantial injury the current two weeks while the exercises were performed.

Even though specific training programs, targeting muscular strength, flexibility or neuromuscular control, reduce injury risk in young athletes (Al Attar et al., 2016; Emery et al., 2015; Hübscher et al., 2010), our results suggest an inverse association. However, it is unlikely that the performance of specific exercises increase the risk of substantial injury prevalence. Instead, it is likely athletes being injured or having pre-injury symptoms that are the ones more motivated to complete the exercises more regularly (Levy, Polman, Clough, & McNaughton, 2006). Consequently, adherence to exercises may therefore be associated with high seasonal substantial injury prevalence. Importantly, our main findings clearly demonstrate that completing the exercises did not reduce the seasonal injury risk compared to not doing the exercises at all.

In line with the seasonal injury data, the small differences in short-term injury risk across exercise category suggest that completing the exercises frequently do not reduce injury risk. More specifically, athletes that completed the exercises more than four times a week did not lower their risk of substantial injury or new injury, compared to not doing the exercises at all. This question the use of prescribing specific exercises based on 9SB. However, the prescribed dose of exercises may not be enough. In line with successful warm-up programmes (Al Attar et al., 2016; LaBella et al., 2011; Longo et al., 2012; Soligard et al., 2008; van Beijsterveldt et al., 2012), a higher volume of exercises, compared to prescribing two or three exercises, may target compensatory movements in different ways and thus reduce injury risk. In addition, since our result is based on self-reported data, an overestimation of the reported frequency of completing the exercises may be present.

The effect of specific exercises is likely dependent on the way they are implemented and that the athletes understand, perform

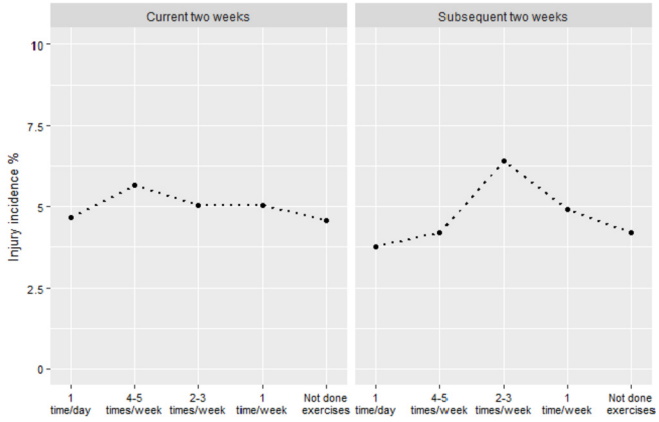

Fig. 3. The risk of new injury the current two weeks while the exercises were performed, as well as the risk of new injury the subsequent two weeks after the exercises were performed.

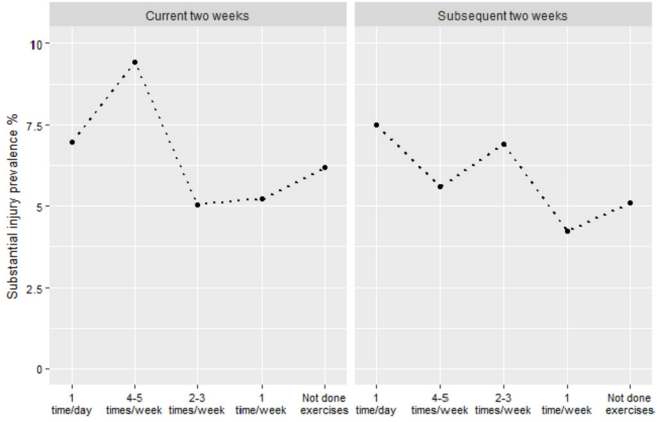

Fig. 4. The risk of substantial injury the current two weeks while the exercises were performed, as well as the risk of substantial injury the subsequent two weeks after the exercises were performed.

and adhere to the prevention program (Keats, Emery, & Finch, 2012). Consequently, there are aspects in the implementation process of the 9SB that could have been improved since 20% of the athletes did not at all complete the prescribed exercises at the start of the study. In addition, by supervising athletes to enhance exercise performance quality may improve the effectiveness of specific exercises (Holme et al., 1999). Besides, in order to enhance adherence to exercises, the coaches may need to be more involved in performing injury prevention programs (Bizzini, Junge, & Dvorak, 2013). More challenging sport specific and demanding exercises may also be needed and implemented continuously as in other successful prevention programs (Hagglund, Atroshi, Wagner, & Walden, 2013; LaBella et al., 2011; Olsen, Myklebust, Engebretsen, Holme, & Bahr, 2005).

It is likely that certain athletes respond more to specific exercises while some athletes likely benefit less from performing exercises, similar to inter-individual variation in training response (Bouchard & Rankinen, 2001; Rice et al., 2002). In addition, the multifactorial nature of injury risk likely confirms this assumption (Meeuwisse, 1994). Therefore, not all athletes may reduce injury risk through changing modifiable intrinsic risk factors (e.g. lack of strength, flexibility, balance etc.). In all four exercise categories there were athletes with no or a low degree of seasonal substantial injury prevalence. Interestingly, the range of seasonal substantial injury prevalence across exercise category was greater for the athletes completing the exercises less than four times a week compared to the athletes completing the exercises four times or more a week. Based on the wide difference in injury data, this might indicate that certain athletes still benefit from conducting specific exercises at least four times a week, but the majority of athletes may need another approach to reduce injury risk or may need to do the exercises more often. Future studies should therefore explore which athletes will respond to specific exercises based on movement screens by adjusting for composite scores, asymmetries or perhaps the results of specific movement tests. Medical personnel, if choosing to use the 9SB, should therefore consider a different approach such as e.g. prescribing a higher training dose of different exercises with progression or regularly supervision of the athlete.

The strength of the study includes the prospective study monitoring athletes over a season and the use of modern injury definitions suited for self-reported data (Clarsen et al., 2013). Besides, a large number of athletes completed the 9SB and were given specific exercises. To fully understand the effect of specific exercises, data were analysed for a season and by short-term. Only injury free athletes were included in short-term analyses, making the cohort homogeneous and unexposed to injury (Song & Chung, 2010). However, the results should be shed in the light of potential limitations. The response rate was lower than in studies with similar methodology by Jacobsson et al. (Jacobsson et al., 2013), von Rosen et al. (von Rosen, Heijne, & Frohm, 2016), but in level with Clarsen at al. (Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014), which potentially may have biased the seasonal injury data and less likely influenced the short-term data analyses.

The results may also be confounded by unmeasured variables, such as training variables or previous injury, which could constitute a threat to the internal validity. At the start of the study we controlled for serious injury, history of previous injury and found no systematic differences across exercise category. However, controlling for previous injury the last year may be influenced by recall bias. In addition, we did not control for the performance quality of exercises. Instead, we tried to reflect a field-on situation where athletes were prescribed exercises and at the same time responsible for doing them correctly. If this approach would have reduced injury risk, it would have been cost-effective and associated with small resources. The exercise group category was constructed based on a single question with multiple-choice options. Consequently, the exact number of times the exercises were performed could not be calculated. In addition, compliance rate was self-reported which may bias the compliance estimate since it is likely that some athletes may overestimate their compliance rate and some underestimate it. However, we still believe a fairly accurate value of compliance rate could be calculated, since we use 52 weeks of data. Even if the intervention did not reduce injury risk, we believe the study-design accurately reflect many aspects of the current clinical practice of injury prevention in adolescent elite athletes.

5. Conclusion

The high injury risk in young elite athletes calls for prevention strategies. Prescribing preventive exercises based on movement screens may lead to that individual based exercises can be developed, which may enhance the effectiveness and adherence to such programs, and hopefully prevent injuries. However, our findings clearly demonstrate that completing specific exercises, based on findings from 9SB, do not reduce the short-term or seasonal injury occurrence in adolescent elite athletes. The prescribing specific exercises were not sufficient or effective to reduce injury risk. Therefore, if choosing to use the 9SB in injury prevention, a different approach is needed, such as e.g. consider the composite scores, the results of specific movement tests, asymmetries or prescribing a higher training dose of different exercises with progression or regularly supervision of the athlete. However, until we know which athletes will benefit from specific exercises, prescribing exercises to decrease injury occurrence based on the 9SB is not recommended.

Conflicts of interest

Declarations of interest: none.

Ethical approval

Ethical approval has been received from the Regional Ethical Committee in Sweden (2011/749-31/3).

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