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Section IV: Sports Medicine & Orthopaedics

Players with high physical fitness are at greater risk of injury in youth football

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Abstract

The aim of this study was to investigate physical fitness, football-specific skills and their association with injury risk in youth football. Altogether 447 male and female players aged 9 to 14 years (median 12 years) participated in performance tests and prospective follow-up. The physical fitness tests included five-jump test for distance, 30-m sprint, football-specific figure of eight agility, countermovement jump, and Yo-Yo intermittent endurance test level 1. The football-specific skill tests included dribbling and passing tests. Injuries and exposure were registered during the 20-week follow-up. Our candidate risk factors were low/high level of physical fitness measured with a composite score of physical fitness tests and low/high level of football-specific skills measured with a composite score of dribbling and passing tests. Secondarily, we investigated performance in individual tests and their association with injury risk. During the follow-up, players reported 565 injuries (264 acute and 301 overuse injuries). High level of physical fitness was associated with increased rate of all injuries (age-, sex- and mean team exposure - adjusted IRR 1.28, 95% CI 1.04–1.58). The level of football-specific skills had no influence on the overall injury rate. Burden of overuse injuries, but not acute injuries was significantly higher in most fit players compared with the players in the reference group (IRR 2.09, 95 % CI 1.04–4.24). In conclusion, most fit players were at greater risk of sustaining injuries in youth competitive football.

Keywords: soccer, sports injuries, adolescent

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Introduction

Football is one of the most popular sports among children and adolescents worldwide. Playing football has many positive health effects including improved cardiovascular fitness, self-esteem and motor skills[1,2] and it encourages physically active lifestyle later in life.[3] However, a negative side-effect of football participation is high risk of injuries. Football-related injuries are alarmingly common already in players under 14 years of age.[4-6] Although most of the football injuries in youth are mild, particular concern is the high proportion of severe injuries, such as fractures, bone stress and sprains.[6] Severe and repetitive sports injuries increase the risk of overweight, obesity and functional deficits.[7] Injury is also one of the reasons to quit sport.[8]

Football is a high-intensity interval sport combined with speed, agility, strength, and endurance. Football players are required to have a high level of physical fitness to endure the demands of the game.[9] Recent epidemiological studies have shown that high rate of injuries is a concern in youth football.[4-6] However, little is known whether physical fitness related factors, such as endurance, power, speed, and agility, are associated with injury risk in youth football. Most of the previous studies investigating physical fitness related risk factors in football have been conducted among adolescents[10-12] or adult players.[13-16] Lower extremity muscle strength has been studied in several of these investigations, whereas endurance, agility, power and speed and their relation to injury risk is far less studied. Moreover, the overall evidence gathered from previous investigations is somewhat conflicting.

Some studies suggest that good endurance is a protective factor against injuries in children and adolescents[17,18] while another study among 12–18-year-old football players found no association between endurance and injury susceptibility.[11] Another recent study by Moseid and colleagues[19] found no relationship between low level of overall physical fitness and injury risk in adolescent elite athletes from various sports. Still, more research on physical fitness related risk factors, especially in early years of sports participation, is needed.

Level of sport-specific skills have been suggested to play a role in injury risk.[10] Martin-Diener and collegues[17] reported that school-children aged 7–9 years with high coordination skills were at increased injury risk compared with less skilled children. A previous study investigating adolescent female football players[10] reported more skilled players being more prone to injury compared with their less skilled counterparts. However, studies on football-specific skills and injury risk in youth football are currently lacking.

In order to prevent sports injuries, it is essential to discover the factors that predispose athletes to injuries. Identifying physical fitness related injury risk factors is worthwhile as they are modifiable, easy to test, and related to team success,[20] which may increase their value for coaches and teams. Currently, there is evidence that neuromuscular training warm-up is effective to both reduce injuries[21-23] as well as improve motor performance in youth football.[24] What is not known is whether the overall level of physical fitness or football-specific skills is associated with greater risk of injury in youth football.

Therefore, the objective of this study was to investigate physical fitness and football-specific skills and their association with injury risk in 9–14-years-old football players. We reviewed the level of physical fitness based on test results for speed, endurance, and agility, and football-specific skills based on tests assessing dribbling and passing skills.

Materials and methods

Study design and participants

This prospective study consists of the control arm (n=733) of a randomized controlled trial investigating the effects of a warm-up program in the prevention of football injuries (ISRCTN14046021).[23]

Every other year, Sami Hyypiä Academy (SHA), the national training and research center of Finnish football, selected about 20 clubs for its own monitoring program during which they followed player development throughout a two-year period. Selected teams, whose players were 9 to 14-year-old girls or boys, participated twice a year in a three-day development monitoring event. In August, we invited all clubs in the SHA to participate in the study. The players, who were official members of the participating teams, were eligible to participate. Players were excluded if they had a severe injury at baseline and if they did not participate both injury data collection and all baseline physical tests. Written informed consent was required from each player and their parent or legal guardian.

Altogether 1424 players agreed to participate in the RCT. Of these, 6 players were excluded due to injury at baseline. Players in the intervention group (n=681) were excluded from the current study. Of the 733 players in the control group, 286 did not participate in the baseline tests and were also excluded. The remaining players (n=447) participated in the baseline tests and prospective follow-up. Two players dropped out during the study (one player quit playing football and one player resigned from the study). The data from these two were included until dropping.

The background information of players was collected by using a questionnaire, which players filled in September–October. The questionnaire included information such as age, sex and starting age of football. The questionnaire was based on previous studies.[25]

Test battery

During the player monitoring events organized by the SHA and held in August to December, the players performed a set of physical fitness and football-specific skill tests. The test battery was designed and conducted by the SHA. Most of the tests have been used in previous studies among young football players.[26-28] The tests were conducted during one day in small groups of players. The order of tests was different among players, but all groups did power and speed tests at the beginning of the testing day. The best result for each player in each test was registered.

The physical fitness tests (Table 1) included 5-jump for distance, 30-m sprint, football-specific figure of eight agility run (Figure 1), countermovement jump (CMJ), and Yo-Yo intermittent endurance test level 1.

The reliability of 5-jump has been assessed as good (ICC=0.91) among adult football players.[29] The reliability of 30-m sprint test has been good (ICC=0.82) among children.[30] To our knowledge, the reliability of football-specific figure of eight agility test has not been previously assessed. However, Mirkov et. al[31] used a same type zigzag test assessing running agility and its reliability was good (ICC=0.84) among adult football players. CMJ has high validity and reliability (ICC=0.95–0.99) among youth and adult football players[27] as well as children.[32] In addition, the reliability of Yo-Yo intermittent endurance level 1 -test has been demonstrated being high among 9–16-years-old football players (ICC=0.95).[28]

The football-specific skill tests included passing (Figure 2) and dribbling tests (Figure 3). These tests have been developed and used in youth football skill competitions organized by the Football Association of Finland. The reliability of the passing ($r=0,81$, $p<0,001$) and dribbling test ($r=0,82$, $p<0,001$) has been good among youth football players.[33]

Assessing the level of physical fitness

We evaluated the level of physical fitness and the level of football-specific skills between participants by calculating composite scores based on performance on physical fitness tests and football-specific skills tests separately. This method was derived from Moseid et al.[19] For each test, we first ranked the players from first to last. Using the sum of these ranks, we identified the quartile of players with the greatest composite score and defined that as least fit group. The quartile of players with the lowest composite score was defined as most fit group. Least and most fit groups were compared to the rest of the cohort (reference group). We identified the players in the highest and lowest quartiles for boys and girls in each age group separately.

We also analysed the association between individual tests and injury risk by using the ranking number of each test. The quartile of players with the greatest ranking number in each test was defined as the poor performance group and the quartile of players with the lowest ranking number in each test as the good performance group and were then compared to the rest of the cohort.

Our main candidate risk factors were the level of physical fitness and the level of football specific skills measured as composite scores of physical fitness and football-specific skills tests. Secondarily, we analysed the association between individual tests and injury risk.

Registration of injuries

Following the physical tests performed during the fall, the prospective follow-up lasted 20 weeks starting from January. Injury data was collected by a standardized weekly SMS to the players or their parents/guardians: "Has your child had any musculoskeletal complaint or injuries during the previous seven days (yes/no)?" If the answer was yes, a study physiotherapist contacted the injured player and/or their parent/guardian to get details of the injury. We used a standardized injury form to record injuries over the phone interview.

Injury definition and categorization of injuries was based on the Fuller et al. consensus statement.[34] We defined an injury as any physical complaint that results from football training or match, regardless of a need for medical attention or time loss from football. We defined an acute injury as an injury that results from a specific identifiable event and overuse injury as an injury that results from repeated microtrauma without identifiable event causing the injury. A player was defined as injured until he or she was able to train and play normally. Injury recovery was monitored by weekly telephone interviews.

We used the Oslo Sports Trauma Research Center Overuse Injury Questionnaire when registering overuse injuries.[35] Players answered the four key questions regarding the consequences of overuse problems on sports participation, training volume, performance, and perceived pain over the telephone interview. Substantial overuse injuries were defined as overuse injuries that lead to moderate or severe reductions in training volume or performance, or an inability to participate. For acute injuries, injury severity was determined using time loss from full participation in training and match. Acute injuries that caused absence of 8 days or more were regarded as substantial injuries. We calculated injury burden separately for acute and overuse injuries. Burden of acute injuries was calculated as the total number of days lost due to an acute injury. Burden of overuse injuries was calculated using the cumulative severity score. We calculated cumulative severity score as the sum of severity scores of each week of injury and was based on the four key questions in the OSTRC questionnaire.[35]

Our primary outcome was the number of all injuries. Secondarily, we performed analyses separately for acute injuries, overuse injuries, substantial acute and overuse injuries, and injury burden.

Registration of exposure

The players reported their weekly exposure hours to football training and match as a part of the SHA program and the data was collected by SHA every month. However, as player reports were incomplete, we used team-based exposure data in the analysis. We calculated mean weekly training exposure for each team using the available individual data and applied team mean training exposure to all players in the team. We gathered the number of matches from the SHA for wintertime (January–March) and from the Finnish Football Association for the competitive season (April–June). We calculated the team match exposure using the standard game durations for each age group and number of players on the field.[34] The team's total match exposure was divided by the number of players in the team and applied each player in the team.

Statistical methods

Characteristics of participants as well as test results were described with means and standard deviations (SD). We used Generalized Linear Mixed Model (GLMM) with negative binomial regression to investigate the incidence rate ratios (IRR) between the least and most fit quartile of players compared with the rest of the players. Primarily, we analysed composite scores of physical fitness and football specific skills on risk of all injuries. Additionally, we analysed separately acute injuries, overuse injuries, substantial injuries, and injury burden. We included sex, age and exposure as adjustment factors based on their possible association with injury risk. In addition to analyses based on composite scores, we analysed individual tests separately. In these analyses, we included sex, age, and exposure as adjustment factors. We also analysed individual tests separately for male and female players using age and exposure as adjustment factors. Club was used as a random effect for all models. P-values < 0.05 were regarded significant and Cohen's d was calculated to measure the effect size (ES) of significant main results.

Results

Altogether 447 players (359 male and 88 female) participated in baseline tests and prospective follow-up. Mean age of the players at baseline was 11.6 years (range 9–14, median 12, SD 1.1). Male players reported starting to play football at significantly ($P<0.001$) younger age (mean 5.4 years, SD 1.3) compared with female players (mean 6.8 years, SD 1.5). No differences were observed in age, height, or body mass between male and female players.

During the 20-week follow-up, 40 191 hours of football exposure was recorded (35 232 hours in practice and 4 959 hours in games). Male players had significantly ($P<0.001$) more exposure both in practice and games (mean 81.8 and 11.4 hours in practice and games, respectively) compared with female players (mean 66.7 and 9.9 hours). There was a small, but non-significant difference in the overall team exposure hours of most fit and least fit players both in male (mean team exposure hours in most fit and least fit, respectively, 94.8 and 90.3 hours) and female players (76.2 and 73.0 hours). Average response rate to the weekly SMS injury questionnaire was 95% and 73% of players responded in all 20 questionnaires.

Injury incidence

During the 20-week follow-up, 311 players (70%) reported at least one injury. One-hundred-eighty-two players (41%) reported an acute injury, whereas 207 players (46%) reported an overuse injury.

Altogether 264 acute injuries were reported (incidence 6.6 injuries/1000 football hours). Most of the acute injuries affected the lower extremities (85% of all acute injuries), ankle (31% of all acute injuries) and knee (20%) being the most commonly injured body parts. Of all acute injuries, 42 (16%) caused time-loss of 8 days or more and were regarded as substantial injuries.

Players reported altogether 301 overuse injuries (incidence 7.5 injuries/1000 football hours). Overuse injuries most commonly affected the knee and heel. Of the 209 players who reported having at least one episode on an overuse injury, 88 reported a knee overuse injury (overall prevalence 20%) and 52 players reported a heel overuse injury (overall prevalence 12%). Of all overuse injuries, 57% were defined as substantial injuries.

Baseline test results

Test results from the baseline tests are displayed in Table 2. The results differed significantly between male and female players in all physical fitness tests as well as football-specific skills tests (P<.001).

Physical fitness, football-specific skills, and injury risk

No differences in injury rates were observed between the least fit players and the reference group in the analyses of overall physical fitness (Table 3). However, most fit players were at significantly greater risk of all injuries (IRR 1.28, 95% CI 1.04–1.58, ES 0.24) when compared with the players in the reference group. Similarly, most fit male players had significantly higher rate of all injuries (IRR 1.30, 95% CI 1.02–1.65, ES 0.19), whereas no differences in injury rates were observed in most fit female players compared with the reference group.

In the analyses of football-specific skills, no statistically significant differences in the rate of all injuries were observed.

Burden of overuse injuries was 2.09-times higher in most fit players compared with the reference group (IRR 2.09, 95% CI 1.04–4.24). No significant differences were observed in the burden of acute injuries between most or least fit groups compared with the reference group. Level of football specific skills was not associated with injury burden (Table 4).

Individual tests and injury risk

Performance in 30-m sprint showed significant associations with nearly all injury types; fastest players had a greater rate of all injuries (IRR 1.51, 95% CI 1.22–1.88), overuse injuries (IRR 1.31, 95% CI 1.03–1.68), and substantial acute and overuse injuries (IRR 1.56, 95% CI 1.15–2.12) (Table 5). Good endurance was associated with greater rate of all injuries (IRR 1.30, 95% CI 1.04–1.62). Good performance in CMJ was associated with greater rate of substantial acute and overuse injuries (IRR 1.57, 95% CI 1.15–2.14).

Of the football-specific skills tests, poor performance in the dribbling test was associated with lower rate of overuse injuries (IRR 0.76, 95% CI 0.57–1.00) and substantial acute and overuse injuries (IRR 0.60, 95% CI 0.41–0.88).

In male players, good performance in 30-m sprint increased (IRR 1.44, 95% CI 1.13–1.83) and poor performance in dribbling decreased the rate of all injuries (IRR 0.75, 95%CI 0.57–0.98). (Supplementary table 1).

In female players, both good and poor performance in 5-jump were associated with greater rate of all injuries (IRR 1.74, 95% CI 1.06–2.84, and 1.78, 1.10–2.89, for good and poor, respectively). Fastest female players in 30-m sprint had a greater rate of all injuries (IRR 1.71, 95% CI 1.07–2.74) and overuse injuries (IRR 1.85, 95% CI 1.12–3.07)(Supplementary table 2).

Discussion

This study was set out to investigate whether physical fitness or football-specific skills are associated with injury risk in 9- to 14-years-old football players. While low level of physical fitness showed no association with injury incidence, high level of physical fitness was associated with greater rate of all injuries. In addition, the burden of overuse injuries was significantly higher in players in the most fit group compared with the players in the reference group. Hence, the most fit players rather than the least fit players appeared to be at risk for injuries in youth football. The level of football-specific skills had no influence on the overall injury rate.

Physical fitness

In organized football, players are often exposed to intensive training already at young age. It has been suggested that high level of physical fitness improves the athlete's ability to tolerate high training loads and the demands of sports and hence may decrease the risk of injury.[14] This theory, however, has not been confirmed in children or adolescent athletes, and the current study actually shows the opposite. According to our results, the most fit youth players had 1.3 times higher rate of injuries compared to players in the average level of fitness. Similar finding was found among male, but not among female players possibly due to low number of females in the cohort. Although only the burden caused by overuse injuries was significantly higher in most fit group compared with the reference group, we also observed notably high number of days lost due to acute injuries in most fit group both in all players as well male players. Hence, not only the rate of injuries but also their burden seems to be higher in most fit youth players.

Several possible differences in exposure, loading, and maturity might explain why most fit players had a higher injury rate compared to their less fit peers. Although the difference in the team-based exposure between the most fit and least fit players was not statistically significant, it is likely that the most fit players train and compete more than the least fit players. Most fit players may also play in other older junior team, which may expose to them high training and competition load. Most fit players presumably are also more involved with the game and probably expose themselves to higher physical loading during the games than their less fit teammates. Certain injury types, such as apophyses and anterior knee pain, are highly common among growing athletes[5,36] and are associated with high amounts of organized training.[37] Furthermore, the individual status of maturity most evidently plays a role in the development of physical fitness as well as injury risk in youth players. Available literature suggests that players with advanced maturity status perform better in physical tests.[38] Early maturers with good performance may also receive more playing time than their average or late matured peers and hence have higher individual match exposure.[39] It is thus possible that the most fit players were early maturers entering the growth spurt, which may partly explain their higher risk of injuries.[40,41] Nevertheless, it is interesting and also worrisome that the most fit youth players seem to be the most vulnerable to injuries. In the current study, we examined physical fitness as a combination of endurance, agility, power, and speed performance. As strength, dynamic balance or neuromuscular control was not analysed in the current study, it remains under speculation whether the most fit players have proper movement skills and technique. Deficits in neuromuscular control have been associated with an increased lower extremity injury risk in youth athletes,[42,43] and might be present also in high-fit players. Neuromuscular training is effective to reduce the risk of injuries in youth football,[21-23] and can improve many aspects of physical performance relevant for football such as dynamic balance and agility,[24,44] and hence, is recommended for all children and adolecents playing football.

Football-specific skills

It has been theorized that players with high ball-handling skills would be more protected from injuries due to their capability to possess and pass the ball and thus avoid contacts with the opposing player.[10] However, contrary to this theory, a study by Soligard and colleagues[10] reported young female football players with good football skills being at greater risk of injuries, especially contact injuries, than less skilled players. The authors suggested that skilled players presumably have more ball possession, are more aggressively involved with the game and are more exposed to tackles and foul play, and hence are at greater risk of injury compared with their less skilled teammates. In our study, we did not see any increase in injury rates in most skilled players. However, in our study the poor performance in the dribbling test was associated with 27 % lower rate of overuse injuries and 40 % lower rate of substantial acute and overuse injuries. A difference between Soligard et al. study and our study was that we measured football-specific skills by using two ball-handling tests (dribbling and passing) based on time, whereas Soligard et al. used coaches' assessment rather than testing the skills. In addition, Soligard et al. study used individual exposure data and the players were female only and older than our players (13- to 17-year-old), and hence, their injury risk might be different. Nevertheless, these studies together suggest that high-skilled players are not protected from injuries in youth football.

Endurance

Poor cardiorespiratory endurance measured both by timed set distance run and timed shuttle run has been regarded as a risk factor for musculoskeletal injuries in adults.[45] The YoYo intermittent endurance tests are widely used in different age groups in football. The YoYo -test is a simple and low-cost test, which has high validity to estimate individual's aerobic capacity.[28] According to our study using the measured distance in the YoYo endurance level 1 -test, good cardiorespiratory endurance was associated with increased rate of all injuries in youth football. This was even though we adjusted analyses for exposure. As we were not able to use individual exposure, it is possible that players with high endurance had a higher match exposure, which may have affected their injury risk. In addition, as the YoYo -test and shuttle run requires deceleration and acceleration properties, which might reflect the ability to load musculoskeletal system, it does not merely measure individual's cardiorespiratory endurance. A previous study by Emery et al.,[11] found no association between predicted maximal oxygen consumption during a 20-m shuttle run and injury risk in 12- to 18-year-old football players. They used player exposure, which gives a more precise estimation of the effects of exposure on injury risk. However, due to differences in participants' age, injury profile as well as differences in study methodology, these studies are not comparable. More studies are needed to confirm our findings on the association of endurance and injury risk in youth football.

Power, speed, and agility

Lower body power, speed and agility are important aspects of physical fitness for a football player. A recent systematic review[46] suggests there is moderate evidence that both reduced and increased lower body power, measured by a standing broad jump or vertical jump with no countermovement, is associated with musculoskeletal injury risk in adult population. Similar level of moderate evidence exists regarding slow sprint speed and its association with injury risk in adults, whereas insufficient evidence exists regarding agility and injury risk in adults.[46] In our study we measured lower body power with CMJ and 5-jump, speed with 30-m sprint, and agility with football-specific figure of eight run test. Good performance in 30-m sprint was associated with increased rate of all injuries, overuse injuries, and substantial acute and overuse injuries in youth football. In addition, good result in CMJ was associated with increased rate of substantial injuries. These findings are somewhat surprising, as one might expect that good performance in these tests that reflect the ability to perform the sport efficiently, would protect players also from many potential injury situations. On the opposite, it is also at least as plausible, that players with good power, speed, and agility are at greater risk of injuries due to increased external and internal forces that result from greater speed and power in different game situations. We consider that players with physical advantages may also have developed a more intensive pace of play throughout games and practices compared to their less developed and less fit peers. Furthermore, it is possible that players with high power and speed performance are advanced in their maturity, which also might predispose them to injuries.

Good sprinting performance showed significant associations with higher injury incidence both in male and female players. Interestingly, in females both good and poor results in 5-jump were related to 1.7- and 1.8-times higher injury rates, respectively. However, as the number of female players in our study was small, subanalyses of female players should be taken with caution.

Strengths and weaknesses

A strength of the current study is that we used several commonly used, sport-specific tests and analyzed them both as a composite score of fitness and individually. In addition, we had a large cohort with a representative sample of children participating in organized and high-level football in Finland. Finally, we registered injuries prospectively using weekly text messages and we had a high response rate throughout the data collection.

This study has limitations. We were unable to register individual exposure but used team exposures instead. Although this is a limitation, it is common procedure to use team-based exposures when individual exposure is not available.[34]

The players performed the tests during August to December, and the injury registration started in January. This is a limitation of our study as the performance of some players might have changed during the period preceding the follow-up. The individual stage of maturity is another confounding factor that might have affected the results of this study. It is common that youth players, especially during the growth-spurt, exhibit altered movement patterns and temporary deficits in coordination and agility. Stage of maturity may have affected not only their performance at the tests, but also their injury risk and time of exposure. Not been able to determine the maturity status of the participants is hence a limitation of our study. Another limitation linked to our youth cohort was the differences in the match duration, number of players in the field, and the size of the field in different age groups. These differences might also have influenced our results.

In our study, we examined only pre-selected components of physical fitness and some aspects, including muscular strength and endurance, and balance were outside the scope of the current study. In addition, other modifiable factors, such as neuromuscular imbalances including decreased knee and hip control, have been suggested being associated with a higher risk of lower extremity injuries in youth athletes[42,43] and male football players,[47] although Räisänen and collegues[48] found no such association in the same cohort of youth football players we are examining. Finally, we acknowledge that the number of players might not be sufficient for subanalyses of females, and these results should be interpretated with caution.

Perspectives

Although various components of physical fitness are regarded as essential for football players, little is known whether physical fitness related factors are associated with injury risk in youth players. To our knowledge this is the first study to investigate physical fitness and football-specific skills as a risk factor for injuries in 9- to 14-year-old football players. We used physical fitness tests measuring endurance, power, speed, and agility, and football-specific skills to identify the most and least fit players as well as the most and least skilled players. Our study showed that the most fit players were at greater risk of sustaining injuries, while no association or lower injury rates were observed in the least fit players compared with the averagely fit reference group. High level of physical fitness seems not to protect youth players from football injuries and might even increase the injury risk. Neuromuscular training warm-up is effective to reduce the risk of injuries in youth football,[21,23] and is essential also for the most fit youth players to keep them healthy and to prevent them from dropping out of sports due to injuries. Coaches are recommended to pay special attention to planning training and competition load for youth players who already perform at high level and take into consideration their overall loading individually also outside team training to avoid overloading of talented youth players. More studies on injury-specific risk factors with individually recorded exposure times in youth football are needed to better understand factors leading to injuries and to efficiently decrease the number of both acute and overuse injuries.

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Conflict of interest

The authors declare having no conflict of interest.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. Faude O, Kerper O, Multhaupt M, et al. Football to tackle overweight in children. Scand J Med Sci Sports 2010;20:103-110.
2. Krustrup P, Hansen PR, Nielsen CM, et al. Structural and functional cardiac adaptations to a 10-week school-based football intervention for 9–10-year-old children. Scand J Med Sci Sports 2014;24:4-9.
3. Tammelin T, Näyhä S, Hills AP, Järvelin M-R. Adolescent participation in sports and adult physical activity. Am J Prev Med 2003;24:22-28.
4. Sokka T, Hilska M, Vasankari T, et al. Females Sustain more Ankle Injuries than Males in Youth Football. Int J Sports Med 2020;41:1017–1023.

5. Leppänen M, Pasanen K, Clarsen B, et al. Overuse injuries are prevalent in children's competitive football: a prospective study using the OSTRC Overuse Injury Questionnaire. Br J Sports Med 2019;53:165–171.
6. Rössler R, Junge A, Chomiak J, Dvorak J, Faude O. Soccer injuries in players aged 7 to 12 years: a descriptive epidemiological study over 2 seasons. Am J Sports Med 2016;44:309-317.
7. Whittaker JL, Woodhouse LJ, Nettel-Aguirre A, Emery CA. Outcomes associated with early post-traumatic osteoarthritis and other negative health consequences 3–10 years following knee joint injury in youth sport. Osteoarthr Cartil 2015;23:1122-1129.
8. Crane J, Temple V. A systematic review of dropout from organized sport among children and youth. Eur Phy Educ Rev 2014;21:114-131.
9. Iaia FM, Ermanno R, Bangsbo J. High-intensity training in football. Int J Sports Physiol Perform 2009;4:291-306.
10. Soligard T, Grindem H, Bahr R, Andersen TE. Are skilled players at greater risk of injury in female youth football? Br J Sports Med 2010;44:1118-1123.
11. Emery CA, Meeuwisse WH, Hartmann SE. Evaluation of risk factors for injury in adolescent soccer: implementation and validation of an injury surveillance system. Am J Sports Med 2005;33:1882-1891.
12. O'Kane JW, Neradilek M, Polissar N, Sabado L, Tencer A, Schiff MA. Risk Factors for Lower Extremity Overuse Injuries in Female Youth Soccer Players. Orthop J Sports Med 2017;5:2325967117733963.
13. Bakken A, Targett S, Bere T, et al. Muscle Strength Is a Poor Screening Test for Predicting Lower Extremity Injuries in Professional Male Soccer Players: A 2-Year Prospective Cohort Study. Am J Sports Med 2018;46:1481-1491.
14. Malone S, Owen A, Mendes B, Hughes B, Collins K, Gabbett TJ. High-speed running and sprinting as an injury risk factor in soccer: Can well-developed physical qualities reduce the risk? J Sci Med Sport 2018;21:257-262.
15. Powers CM, Ghoddosi N, Straub RK, Khayambashi K. Hip strength as a predictor of ankle sprains in male soccer players: A prospective study. J Athl Train 2017;52:1048-1055.
16. van Dyk N, Bahr R, Whiteley R, et al. Hamstring and Quadriceps Isokinetic Strength Deficits Are Weak Risk Factors for Hamstring Strain Injuries: A 4-Year Cohort Study. Am J Sports Med 2016;44:1789-1795.
17. Martin-Diener E, Wanner M, Kriemler S, Martin BW. Associations of objectively assessed levels of physical activity, aerobic fitness and motor coordination with injury risk in school children aged 7–9 years: a cross-sectional study. BMJ Open 2013;3.
18. Emery CA. Risk factors for injury in child and adolescent sport: a systematic review of the literature. Clin J Sport Med 2003;13:256-268.
19. Moseid CH, Myklebust G, Slaastuen MK, et al. The association between physical fitness level and number and severity of injury and illness in youth elite athletes. Scand J Med Sci Sports 2019;29:1736-1748.
20. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Physical fitness, injuries, and team performance in soccer. Med Sci Sports Exerc 2004;36:278-285.
21. Rössler R, Junge A, Bizzini M, et al. A Multinational Cluster Randomised Controlled Trial to Assess the Efficacy of '11+ Kids': A Warm-Up Programme to Prevent Injuries in Children's Football. Sports Medicine 2017.

22. Zarei M, Abbasi H, Namazi P, Asgari M, Rommers N, Rössler R. The 11+ Kids warm-up programme to prevent injuries in young Iranian male high-level football (soccer) players: A cluster-randomised controlled trial. J Sci Med Sport 2019.
23. Hilska M, Leppänen M, Vasankari T, et al. Neuromuscular Training Warm-up Prevents Acute Noncontact Lower Extremity Injuries in Children's Soccer: A Cluster Randomized Controlled Trial. Orthop J Sports Med 2021;9:April 2021. doi:2010.1177/23259671211005769.
24. Rossler R, Donath L, Bizzini M, Faude O. A new injury prevention programme for children's football--FIFA 11+ Kids--can improve motor performance: a cluster-randomised controlled trial. J Sports Sci 2016;34:549-556.
25. Pasanen K, Rossi MT, Parkkari J, et al. Predictors of lower extremity injuries in team sports (PROFITS-study): a study protocol. BMJ Open Sport Exerc Med 2015;1:e000076.
26. Vänttinen T, Blomqvist M, Häkkinen K. Development of body composition, hormone profile, physical fitness, general perceptual motor skills, soccer skills and on-the-ball performance in soccer-specific laboratory test among adolescent soccer players. J Sports Sci Med 2010;9:547.
27. Rodríguez-Rosell D, Mora-Custodio R, Franco-Márquez F, Yáñez-García JM, González-Badillo JJ. Traditional vs. sport-specific vertical jump tests: reliability, validity, and relationship with the legs strength and sprint performance in adult and teen soccer and basketball players. J Strength Cond Res 2017;31:196-206.
28. Grgic J, Oppici L, Mikulic P, Bangsbo J, Krustrup P, Pedisic Z. Test-Retest Reliability of the Yo-Yo Test: A Systematic Review. Sports Med 2019;49:1547-1557.
29. Chamari K, Chaouachi A, Hambli M, Kaouech F, Wisløff U, Castagna C. The five-jump test for distance as a field test to assess lower limb explosive power in soccer players. J Strength Cond Res 2008;22:944-950.
30. Runacres A, Bezodis N, Mackintosh K, McNarry M. The reliability of force-velocity-power profiling during over-ground sprinting in children and adolescents. J Sports Sci 2019;37:2131-2137.
31. Mirkov D, Nedeljkovic A, Kukolj M, Ugarkovic D, Jaric S. Evaluation of the reliability of soccer-specific field tests. J Strength Cond Res 2008;22:1046-1050.
32. Fernandez-Santos JR, Ruiz JR, Cohen DD, Gonzalez-Montesinos JL, Castro-Piñero J. Reliability and Validity of Tests to Assess Lower-Body Muscular Power in Children. J Strength Cond Res 2015;29:2277-2285.
33. Vänttinen T. *Growth-associated variation in body size, hormonal status, physical performance characteristics and perceptual-motor skills in Finnish young soccer players: a two-year follow-up study in the U11, U13 and U15 age groups*: Studies in sport, physical education and health2013.
34. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Br J Sports Med 2006;40:193-201.
35. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. Br J Sports Med 2013;47:495-502.
36. Wik EH, Lolli L, Chamari K, et al. Injury patterns differ with age in male youth football: a four-season prospective study of 1111 time-loss injuries in an elite national academy. Br J Sports Med 2021;55:794-800.

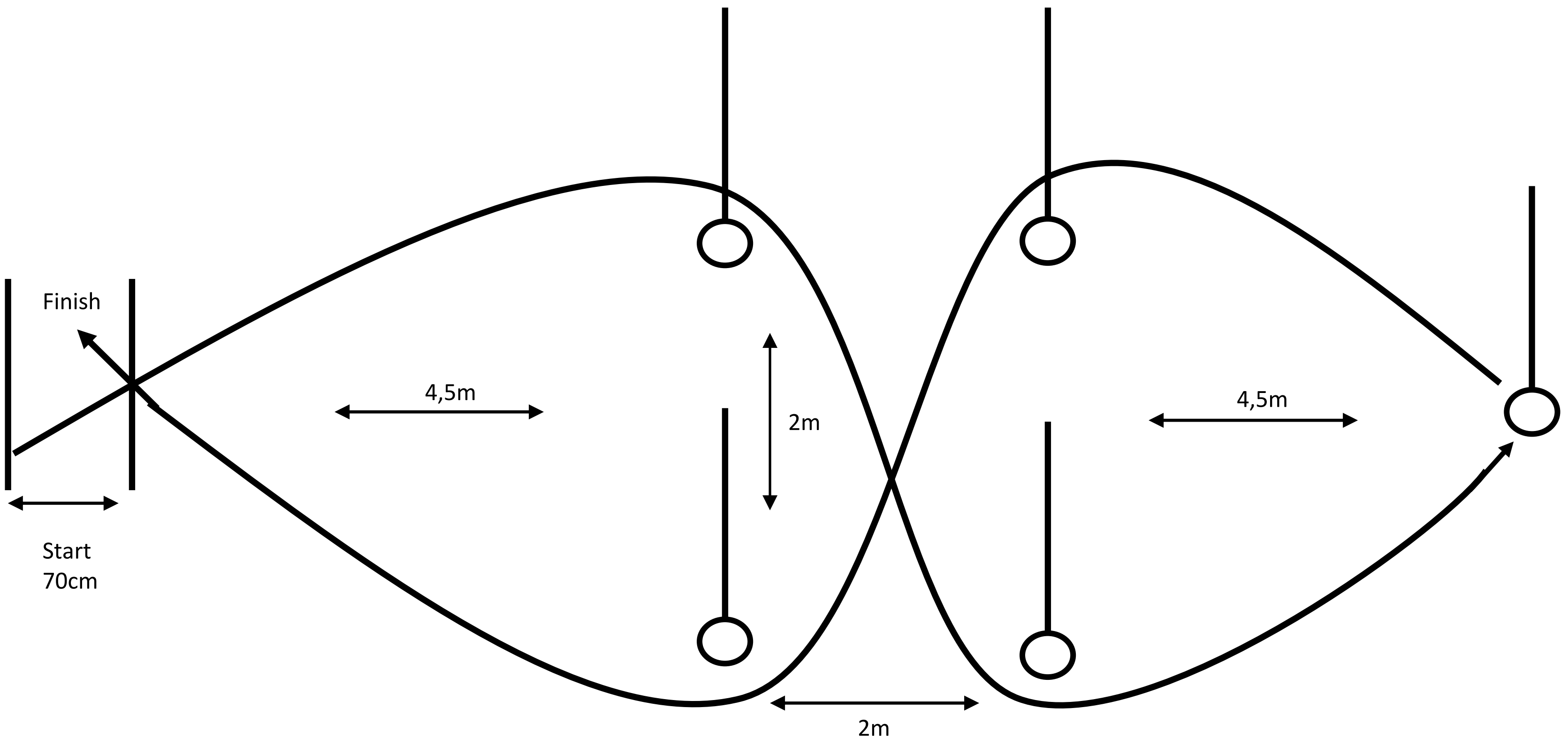
37. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. Am J Sports Med 2015;43:794-801.
38. Radnor JM, Staines J, Bevan J, et al. Maturity Has a Greater Association than Relative Age with Physical Performance in English Male Academy Soccer Players. Sports (Basel) 2021;9.
39. Malina RM, Rogol AD, Cumming SP, Coelho e Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. Br J Sports Med 2015;49:852-859.
40. Materne O, Chamari K, Farooq A, et al. Association of Skeletal Maturity and Injury Risk in Elite Youth Soccer Players: A 4-Season Prospective Study With Survival Analysis. Orthop J Sports Med 2021;9:2325967121999113.
41. Monasterio X, Gil SM, Bidaurrazaga-Letona I, et al. The burden of injuries according to maturity status and timing: A two-decade study with 110 growth curves in an elite football academy. European journal of sport science 2021:1-11.
42. Räisänen AM, Pasanen K, Krosshaug T, et al. Association between frontal plane knee control and lower extremity injuries: a prospective study on young team sport athletes. BMJ Open Sport Exerc Med 2018;4:10.1136/bmjsem-2017-000311.
43. Leppänen M, Rossi MT, Parkkari J, et al. Altered hip control during a standing knee-lift test is associated with increased risk of knee injuries. Scand J Med Sci Sports 2020;30:922-931.
44. Pomares-Noguera C, Ayala F, Robles-Palazon FJ, et al. Training Effects of the FIFA 11+ Kids on Physical Performance in Youth Football Players: A Randomized Control Trial. Front Pediatr 2018;6:40.
45. Lisman PJ, de la Motte SJ, Gribbin TC, Jaffin DP, Murphy K, Deuster PA. A Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 1—Cardiorespiratory Endurance. J Strength Cond Res 2017;31:1744-1757.
46. de la Motte SJ, Lisman P, Gribbin TC, Murphy K, Deuster PA. Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 3—Flexibility, Power, Speed, Balance, and Agility. J Strength Cond Res 2019;33:1723-1735.
47. Read PJ, Oliver JL, De Ste Croix MB, Myer GD, Lloyd RS. Neuromuscular Risk Factors for Knee and Ankle Ligament Injuries in Male Youth Soccer Players. Sports Med 2016;46:1059-1066.
48. Räisänen AM, Arkkila H, Vasankari T, et al. Investigation of knee control as a lower extremity injury risk factor: A prospective study in youth football. Scand J Med Sci Sports 2018;28:2084-2092.

Figure legends

Figure 1. Football-specific figure of eight agility test.

Figure 2. Passing test.

Figure 3. Dribbling test.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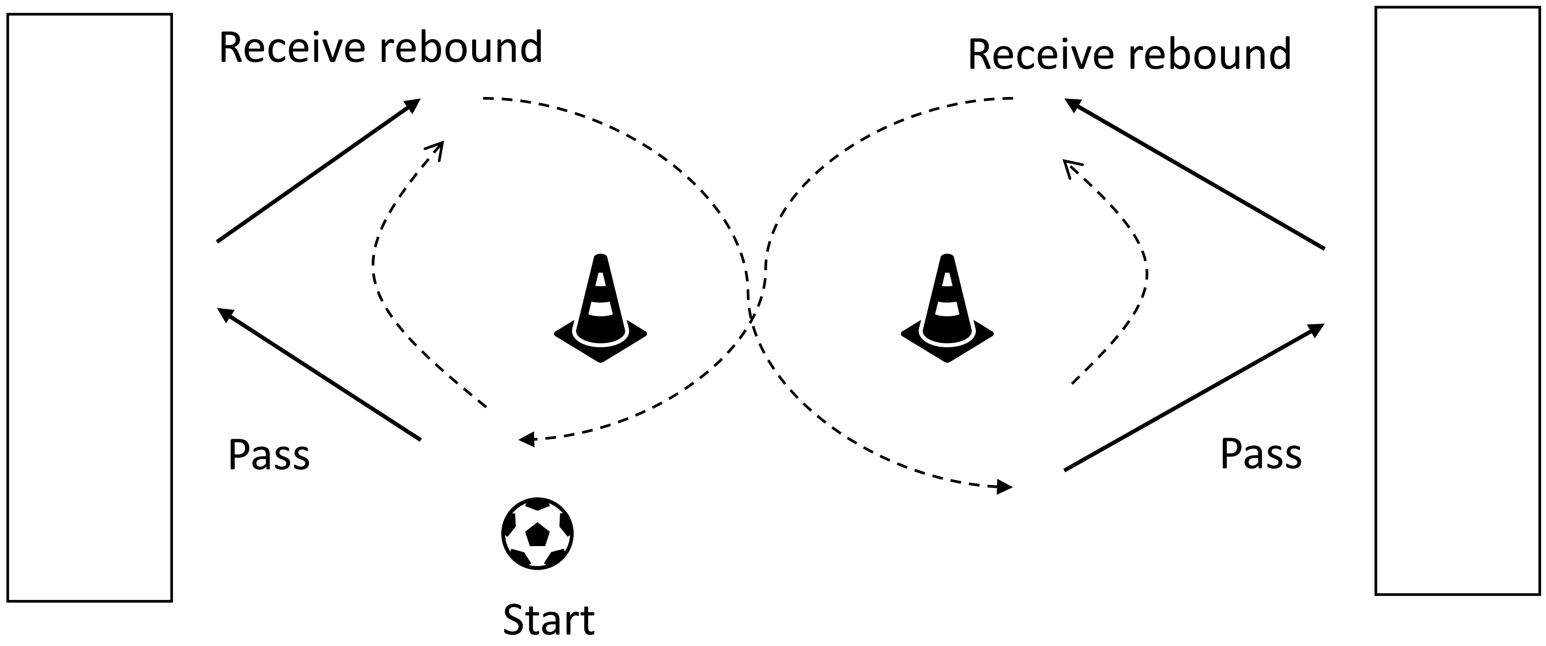
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Pass
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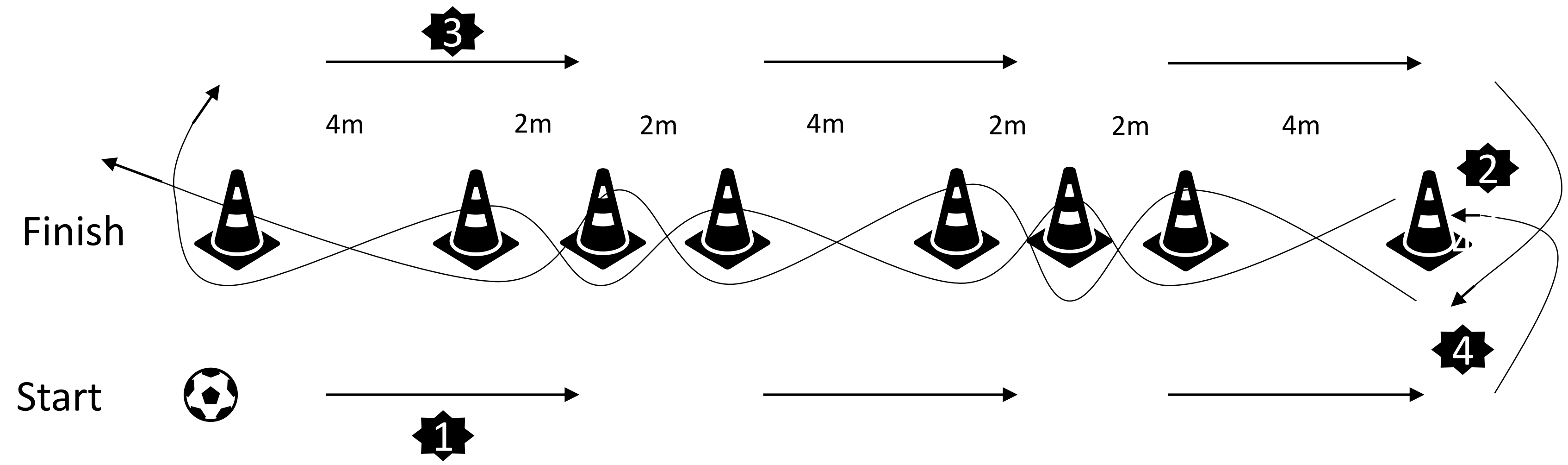

1=Straight run with ball (at least 3 touches before turn)
2=Dribbling
3=Straight run with ball (at least 3 touches before turn)
4=Dribbling

Table 1. Test battery. The best result for each player in each test was registered.

Test	Test description	Physical properties
Physical fitness tests		
5-jump	Player started from the starting line standing in shoulder width position. Player jumped 5 jumps with alternative legs and after the last jump landed on both feet into sandpit. The results were recorded at the accuracy of one centimetre. The player performed three trials.	Explosive power
30-m sprint	The player started 0.70m behind the photocells, which triggered the start of the time signal. The time-stopping photocells were placed at the distance of 30m from the starting line. The result was measured seconds by photocells at the accuracy of a hundred of seconds. The player performed two trials.	Speed
Football-specific figure of eight agility	The player ran back and forth to touch a pole placed 11m from a starting line (Figure 1). On the way to the pole as well as on the way back to the finish line the player performed a slalom run in a 2 m x 2 m rectangle placed 4.5m apart from the starting line and from the pole. A photocell timer recorded the result with a precision of one hundredth of a second. The player performed two successful trials.	Speed and agility
Countermovement jump	The jump was performed with hands placed on the hips throughout the test. The player squatted down, then immediately jumped vertically as high as possible, landing back on both feet at the same time. During time spent in the air, full extension in the hip, knee and ankle joints were maintained (bending legs was not allowed). Based on the flight time the system automatically displayed the result of measured jump in centimetres. The player performed two successful trials.	Lower-body power
Yo-Yo Level 1	In endurance test the player ran continuously between two lines 20m apart in time of the trigger signal played from a CD. At the beginning the velocity was 8.5 km/h and the speed increased by 0.5 km/h each minute. The player continued running between the two lines until the player failed to reach the line for two consecutive ends at the onset of trigger signal. The result was the distance travelled in meters, including the last 20m. The player did the test once.	Endurance
Football-specific skill tests		
Passing	The passing test included two cones placed 6m apart from each other and 2m wide passing walls placed 7m apart from the cones (Figure 2). Performance time started when the player kicked	Agility with a ball

	the first pass against the wall. Then the player repeated the cycle: pass - receive rebound - dribble between cones - pass to the other wall. The performance ended when the 10th pass hit the passing wall. Passes were performed alternately with the right and left feet. Performance time was measured with a stopwatch with a precision of a second. Maximum time was 60s. The player performed two trials.	
Dribbling	The player took the ball and ran straight to a pole which was set to 20 meters from the starting line (Figure 3). The player had to touch the ball at least 3 times before the pole. Then the player dribbled back to the starting line between the poles which were placed 2 to 4 meters apart from each other. The same straight run-dribbling action was repeated from the other side to complete the test. Performance time was measured with a stopwatch with a precision of a second. Maximum time was 60s. The player performed two trials.	Agility with a ball

Table 2. Test results in male and female players according to age (mean and standard deviation).

	5-jump (m)	30-m sprint (s)	Figure of eight (s)	CMJ (cm)	Yo-Yo (m)	Passing (s)	Dribbling (s)	Fitness score*	Football-specific skills score**
Male (n=359)	**9.4 (0.9)**	**4.9 (0.3)**	**7.2 (0.3)**	**24.6 (4.1)**	**1944 (341)**	**41.5 (5.9)**	**27.4 (3.0)**	**1005 (514)**	**383 (219)**
9–10 y (n=72)	8.6 (0.6)	5.2 (0.2)	7.4 (0.3)	21.9 (2.8)	1684 (290)	45.3 (5.9)	29.0 (2.8)	1498 (350)	560 (175)
11 y (n=80)	9.1 (0.7)	5.0 (0.2)	7.3 (0.3)	23.8 (3.5)	1876 (304)	42.0 (5.6)	27.3 (2.1)	1211 (424)	400 (200)
12 y (n=107)	9.6 (0.8)	4.9 (0.2)	7.2 (0.2)	24.9 (3.9)	2013 (319)	40.7 (4.9)	26.8 (2.1)	887 (435)	343 (203)
13–14 y (n=100)	10.2 (0.8)	4.7 (0.2)	7.0 (0.2)	26.9 (4.3)	2114 (301)	39.4 (5.7)	26.9 (4.1)	613 (375)	285 (202)
Female (n=88)	**9.1 (0.8)**	**5.1 (0.4)**	**7.6 (0.4)**	**22.9 (3.6)**	**1600 (313)**	**48.1 (6.9)**	**30.2 (3.1)**	**1435 (498)**	**637 (188)**
9–10 y (n=20)	8.3 (0.5)	5.5 (0.3)	7.9 (0.4)	21.0 (2.6)	1296 (201)	55.1 (4.6)	33.0 (2.5)	1900 (272)	807 (74)
11 y (n=22)	8.9 (0.8)	5.3 (0.4)	7.6 (0.4)	22.5 (4.4)	1460 (233)	49.6 (5.9)	30.9 (2.6)	1624 (478)	707 (144)
12 y (n=26)	9.4 (0.5)	5.0 (0.2)	7.5 (0.2)	23.0 (3.0)	1712 (220)	44.0 (4.2)	29.1 (2.8)	1301 (350)	553 (161)
13 y (n=20)	9.8 (0.7)	4.8 (0.1)	7.4 (0.2)	25.3 (2.8)	1913 (213)	44.7 (7.0)	27.9 (2.0)	935 (302)	500 (182)

CMJ=countermovement jump. *Sum of individual ranks on 5-jump, 30-m sprint, Figure of eight, CMJ, and Yo-Yo tests. **Sum of individual ranks on dribbling and passing tests.

Table 3. The association between the level of physical fitness and football-specific skills and the number of injuries described with incidence rate ratio (IRR) and 95% confidence interval (CI). Average number of injuries per player in each group is given as mean and standard deviation (SD). The level of physical fitness was assessed by calculating a composite score based on performance in five physical fitness tests and the level of football-specific skills by calculating a composite score based on performance in two football-specific skills tests. The most fit and most skilled quartile of players as well as the least fit and least skilled quartile of players were compared to the rest of the cohort (reference group).

		All injuries		Acute injuries		Overuse injuries		Substantial acute and overuse injuries	
	Level of fitness	Mean (SD)	IRR (95% CI)	Mean (SD)	IRR (95% CI)	Mean (SD)	IRR (95% CI)	Mean (SD)	IRR (95% CI)
All players (n=447)[†]									
Physical fitness	most fit	1.6 (1.4)	1.28 (1.04 to 1.58)*	0.7 (1.0)	1.16 (0.86 to 1.57)	0.9 (0.9)	1.23 (0.96 to 1.57)	0.7 (0.8)	1.44 (1.05 to 1.96)
	reference	1.2 (1.2)	1	0.6 (0.8)	1	0.6 (0.9)	1	0.4 (0.6)	1
	least fit	1.1 (1.3)	0.99 (0.79 to 1.24)	0.6 (1.0)	1.12 (0.83 to 1.52)	0.6 (0.8)	0.88 (0.67 to 1.16)	0.4 (0.7)	1.02 (0.71 to 1.47)
Football-specific skills	most fit	1.4 (1.4)	1.09 (0.88 to 1.37)	0.7 (0.9)	1.06 (0.79 to 1.43)	0.8 (1.0)	1.11 (0.87 to 1.43)	0.6 (0.7)	1.00 (0.73 to 1.38)
	reference	1.3 (1.2)	1	0.6 (0.9)	1	0.7 (0.9)	1	0.5 (0.7)	1
	least fit	1.0 (1.3)	0.81 (0.64 to 1.03)	0.6 (0.9)	0.92 (0.68 to 1.25)	0.5 (0.7)	0.80 (0.61 to 1.06)	0.4 (0.6)	0.77 (0.54 to 1.11)
Male players (n=359)[‡]									
Physical fitness	most fit	1.5 (1.3)	1.30 (1.02 to 1.65)*	0.7 (0.9)	1.15 (0.83 to 1.59)	0.9 (0.9)	1.17 (0.90 to 1.52)	0.7 (0.8)	1.23 (0.92 to 1.65)
	reference	1.2 (1.2)	1	0.6 (0.8)	1	0.6 (0.8)	1	0.5 (0.6)	1
	least fit	1.1 (1.4)	1.03 (0.80 to 1.34)	0.6 (1.0)	1.19 (0.86 to 1.65)	0.6 (0.8)	0.93 (0.70 to 1.23)	0.4 (0.7)	1.06 (0.77 to 1.44)
Football-specific skills	most fit	1.4 (1.3)	1.08 (0.85 to 1.38)	0.6 (0.8)	1.03 (0.74 to 1.43)	0.8 (1.0)	1.15 (0.89 to 1.50)	0.5 (0.7)	1.01 (0.75 to 1.36)
	reference	1.3 (1.2)	1	0.6 (0.9)	1	0.7 (0.8)	1	0.5 (0.7)	1
	least fit	1.0 (1.3)	0.80 (0.61 to 1.04)	0.6 (1.0)	0.96 (0.69 to 1.34)	0.4 (0.7)	0.83 (0.62 to 1.11)	0.4 (0.6)	0.85 (0.62 to 1.17)
Female players (n=88)[‡]									
Physical fitness	most fit	1.9 (2.0)	1.38 (0.85 to 2.26)	0.8 (1.4)	1.23 (0.60 to 2.53)	1.3 (1.1)	1.40 (0.85 to 2.33)	0.7 (0.8)	1.52 (0.83 to 2.80)
	reference	1.2 (1.3)	1	0.5 (0.9)	1	0.7 (0.9)	1	0.4 (0.6)	1
	least fit	1.1 (1.0)	0.86 (0.50 to 1.47)	0.6 (0.7)	0.97 (0.46 to 2.04)	0.5 (0.7)	0.72 (0.39 to 1.34)	0.3 (0.6)	1.03 (0.52 to 2.05)
Football-specific skills	most fit	1.6 (1.9)	1.17 (0.70 to 1.94)	0.9 (1.3)	1.17 (0.58 to 2.38)	0.9 (1.0)	0.95 (0.54 to 1.69)	0.6 (0.7)	1.13 (0.61 to 2.08)
	reference	1.3 (1.4)	1	0.5 (0.9)	1	0.8 (1.0)	1	0.4 (0.7)	1
	least fit	1.2 (1.0)	0.88 (0.51 to 1.52)	0.5 (0.6)	0.91 (0.42 to 1.95)	0.7 (0.7)	0.76 (0.41 to 1.41)	0.3 (0.5)	0.73 (0.36 to 1.48)

†IRRs adjusted for sex, age, and exposure.
‡IRRs adjusted for age and exposure. **P*-value <0.05

Table 4. The association between the level of physical fitness and football-specific skills and the injury burden of acute injuries (measured as the number of days lost due to an injury) and overuse injuries (measured by cumulative severity score) described with incidence rate ratio (IRR) and 95% confidence interval (CI). Average number of days lost and cumulative severity score per player in each group is given as mean and standard deviation (SD). The level of physical fitness was assessed by calculating a composite score based on performance in five physical fitness tests and the level of football-specific skills by calculating a composite score based on performance in two football-specific skills tests. The most fit and most skilled quartile of players as well as the least fit and least skilled quartile of players were compared to the rest of the cohort (reference group).

		Burden: acute injuries, number of days lost		Burden: overuse injuries, cumulative severity score	
	Level of fitness	Mean (SD)	IRR (95% CI)	Mean (SD)	IRR (95% CI)
All players (n=447)†					
Physical fitness	most fit	6.4 (17.0)	1.34 (0.72 to 2.48)	177.0 (260.4)	2.09 (1.04 to 4.24)*
	reference	4.8 (11.2)	1	80.9 (170.2)	1
	least fit	3.0 (6.9)	0.72 (0.39 to 1.35)	77.4 (161.8)	0.97 (0.48 to 1.95)
Football-specific skills	most fit	5.9 (15.4)	1.29 (0.69 to 2.43)	122.5 (212.2)	1.07 (0.53 to 2.18)
	reference	4.5 (9.6)	1	115.4 (220.1)	1
	least fit	4.1 (13.0)	0.85 (0.45 to 1.59)	60.3 (114.7)	0.61 (0.30 to 1.23)
Male players (n=359)‡					
Physical fitness	most fit	7.4 (18.6)	1.54 (0.77 to 3.08)	157.1 (237.2)	2.00 (0.90 to 4.43)
	reference	5.4 (12.1)	1	76.5 (12.1)	1
	least fit	3.3 (7.5)	0.79 (0.39 to 1.59)	71.6 (144.6)	0.96 (0.44 to 2.13)
Football-specific skills	most fit	6.5 (16.7)	1.10 (0.54 to 2.25)	104.9 (186.2)	0.96 (0.43 to 2.13)
	reference	5.1 (10.4)	1	112.5 (213.8)	1
	least fit	4.8 (14.4)	0.96 (0.47 to 1.95)	51.2 (105.8)	0.58 (0.26 to 1.27)
Female players (n=88)‡					
Physical fitness	most fit	1.6 (3.2)	0.97 (0.26 to 3.58)	262.3 (339.0)	2.47 (0.53 to 11.59)
	reference	2.6 (6.2)	1	97.7 (169.7)	1
	least fit	1.7 (3.2)	0.64 (0.17 to 2.36)	102.1 (223.9)	1.11 (0.24 to 5.13)
Football-specific skills	most fit	3.5 (7.5)	1.45 (0.41 to 5.16)	196.5 (292.1)	1.52 (0.32 to 7.14)
	reference	2.0 (4.5)	1	126.6 (245.5)	1
	least fit	1.2 (2.5)	0.53 (0.14 to 1.98)	99.4 (143.4)	0.80 (0.17 to 3.81)

†IRRs adjusted for sex, age and exposure.

‡IRRs adjusted for age and exposure.

Table 5. The association between the performance in individual physical fitness and football-specific skills tests and the number of injuries in all players (n=447) described with incidence rate ratio (IRR) and 95% confidence interval (CI). Average number of injuries per player in each group is given as mean and standard deviation (SD). The quartile of players with best performance in each test was defined as good performance group and the quartile of players with poorest performance in each test was defines as poor performance group. Good and poor performance groups were compared to the rest of the cohort (reference group).

	All injuries		Acute injuries		Overuse injuries		Substantial acute and overuse injuries	
	Mean (SD)	IRR (95% CI)	Mean (SD)	IRR (95% CI)	Mean (SD)	IRR (95% CI)	Mean (SD)	IRR (95% CI)
Physical fitness tests								
5-jump								
good (n=103)	1.4 (1.4)	1.15 (0.92 to 1.45)	0.6 (0.9)	1.08 (0.79 to 1.47)	0.8 (1.0)	1.10 (0.85 to 1.42)	0.6 (0.7)	1.25 (0.91 to 1.71)
reference (n=237)	1.2 (1.3)	1	0.6 (0.8)	1	0.7 (0.9)	1	0.5 (0.7)	1
poor (n=107)	1.2 (1.3)	1.08 (0.85 to 1.37)	0.7 (1.1)	1.19 (0.88 to 1.60)	0.6 (0.7)	0.84 (0.64 to 1.11)	0.4 (0.6)	1.07 (0.75 to 1.52)
30-m sprint								
good (n=109)	1.7 (1.5)	1.51 (1.22 to 1.88)*	0.7 (1.1)	1.31 (0.98 to 1.76)	0.9 (1.0)	1.31 (1.03 to 1.68)*	0.7 (0.8)	1.56 (1.15 to 2.12)*
reference (n=230)	1.1 (1.1)	1	0.5 (0.8)	1	0.6 (0.8)	1	0.4 (0.6)	1
poor (n=108)	1.3 (1.3)	1.22 (0.97 to 1.55)	0.6 (1.0)	1.20 (0.89 to 1.62)	0.6 (0.8)	1.02 (0.79 to 1.34)	0.4 (0.7)	1.16 (0.81 to 1.66)
Figure of eight								
good (n=108)	1.3 (1.2)	0.92 (0.73 to 1.16)	0.5 (0.8)	0.89 (0.65 to 1.21)	0.8 (0.9)	1.04 (0.81 to 1.34)	0.5 (0.7)	1.01 (0.73 to 1.39)
reference (n=227)	1.3 (1.3)	1	0.6 (0.9)	1	0.7 (0.9)	1	0.5 (0.7)	1
poor (n=112)	1.1 (1.4)	0.83 (0.66 to 1.05)	0.6 (1.0)	0.96 (0.71 to 1.30)	0.5 (0.8)	0.86 (0.66 to 1.12)	0.4 (0.7)	0.93 (0.66 to 1.32)
CMJ								
good (n=117)	1.4 (1.3)	1.20 (0.96 to 1.50)	0.6 (0.9)	1.09 (0.81 to 1.48)	0.8 (0.9)	1.15 (0.89 to 1.47)	0.6 (0.8)	1.57 (1.15 to 2.14)*
reference (n=215)	1.2 (1.2)	1	0.5 (0.8)	1	0.6 (0.9)	1	0.4 (0.6)	1
poor (n=115)	1.3 (1.4)	1.16 (0.92 to 1.46)	0.7 (1.0)	1.22 (0.91 to 1.63)	0.6 (0.8)	0.96 (0.74 to 1.26)	0.5 (0.7)	1.26 (0.89 to 1.79)
Yo-Yo								
good (n=107)	1.5 (1.4)	1.30 (1.04 to 1.62)*	0.6 (1.0)	1.14 (0.85 to 1.54)	0.9 (0.9)	1.23 (0.96 to 1.57)	0.6 (0.7)	1.32 (0.96 to 1.81)
reference (n=230)	1.2 (1.2)	1	0.6 (0.8)	1	0.6 (0.8)	1	0.4 (0.7)	1
poor (n=110)	1.2 (1.3)	1.01 (0.81 to 1.29)	0.6 (1.0)	1.07 (0.79 to 1.45)	0.6 (0.8)	0.93 (0.71 to 1.21)	0.4 (0.6)	1.04 (0.73 to 1.48)
Fooball-specific skills tests								
Passing								
good (n=119)	1.4 (1.3)	1.00 (0.80 to 1.25)	0.6 (0.8)	0.92 (0.68 to 1.24)	0.8 (0.9)	1.10 (0.86 to 1.41)	0.5 (0.8)	0.99 (0.72 to 1.37)
reference (n=228)	1.3 (1.3)	1	0.6 (0.9)	1	0.7 (0.8)	1	0.5 (0.6)	1

poor (n=100)	1.2 (1.3)	0.90 (0.71 to 1.15)	0.6 (0.9)	0.91 (0.67 to 1.25)	0.6 (0.9)	0.99 (0.75 to 1.30)	0.5 (0.7)	0.99 (0.69 to 1.40)
Dribbling								
good (n=110)	1.4 (1.4)	1.02 (0.82 to 1.28)	0.6 (0.9)	1.07 (0.79 to 1.44)	0.8 (1.0)	1.06 (0.83 to 1.35)	0.5 (0.7)	0.87 (0.63 to 1.20)
reference (n=229)	1.3 (1.3)	1	0.6 (0.8)	1	0.7 (0.9)	1	0.5 (0.7)	1.00
poor (n=108)	1.1 (1.3)	0.80 (0.63 to 1.02)	0.6 (1.0)	1.05 (0.77 to 1.42)	0.4 (0.7)	0.76 (0.57 to 1.00)*	0.3 (0.6)	0.60 (0.41 to 0.88)*

All IRRs adjusted for sex, age, and exposure hours. **P*-value <0.05.