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Running title: motor performance and injury risk in children

Abstract

Purpose. Physical activity related injuries in children constitute a costly public health matter. The influence of motor performance on injury risk is unclear. The purpose was to examine if motor performance was a risk factor of traumatic and overuse lower extremity injuries in a normal population of children. **Methods.** This study included 1244 participants from 8 to 14-years-old at baseline, all participating in "the Childhood Health, Activity and Motor Performance School Study Denmark". The follow-up period was up to 15 months. The motor performance tests were static balance, single leg hop for distance, core stability tests, vertical jump, shuttle run, and a cardiorespiratory fitness test. Lower extremity injuries were registered by clinicians by weekly questionnaires and classified according to the ICD-10 system. **Results.** Poor balance increased risk for traumatic injury in the foot region (IRR=1.09-1.15), and good performance in single leg hop for distance protected against traumatic knee injuries (IRR=0.66-0.68). Good performance in core stability tests and vertical jump increased the risk for traumatic injuries in the foot region (IRR=1.12-1.16). Poor balance increased the risk for overuse injuries in the foot region (IRR=1.65), as did good performance in core stability tests and shuttle run, especially for knee injuries (IRR=1.07-1.18). **Conclusions.** Poor balance (sway) performance was a consistent predictor of traumatic injuries, in particular for traumatic ankle injuries. Good motor performance (core stability, vertical jump, shuttle run) was positively associated with traumatic and overuse injuries, and negatively (single leg hop) associated with traumatic injuries, indicating different influence on injury risk. Previous injury was a confounder affecting the effect size and the significance. More studies are needed to consolidate the findings, to clarify the influence of different performance tests on different types of injuries and to examine the influence of behaviour in relation to injury risk. **Keywords:** injury, motor performance, children, sway

Introduction

Physical activity related injuries have been established as a leading cause of paediatric injuries in western countries (15), thereby constituting an important and costly public health matter in terms of both direct and indirect costs (7).

The registration of physical activity related injuries in children has primarily included traumatic injuries registered at emergency departments or by medical doctors (15). A new data collection method, the Short Messaging Service-Track questionnaire (SMS-Track), can be used to send out a short weekly cell phone questionnaire concerning musculoskeletal complaints (38), and has given the opportunity to register complaints by the use of the "any physical complaint criteria" (13). This has led to a more detailed and comprehensive registration of injuries in children, including both traumatic injuries and overuse injuries. Traumatic injuries can be defined as injuries resulting from a single, specific, and identifiable event whereas overuse injuries are caused by repeated micro trauma without a single, identifiable event responsible for the injury (13). In a Danish study, the SMS-Track was used as the underlying method to collect information on incidence and prevalence of both traumatic and overuse injuries among 6- to 12-year-old children (18, 38). This method presented that approximately one third of injuries in children were traumatic, two thirds were overuse injuries (18). The location of the overuse injuries was mainly in the lower extremity (94.5%). Furthermore, the lower extremity is one of the most common regions to sustain traumatic injuries (28).

Several risk factors for physical activity related injuries in child populations have been identified (11). Non-modifiable factors, such as gender and age (4, 20), and modifiable factors such as physical fatigue (12), overweight (19), collisions and falls (32), decreased proprioception and lack of sport specific training (11) have been identified as risk factors of primarily traumatic injury. Having had a previous injury was identified as a risk factor in studies of adults. Comparison of adults with and without previous injuries showed that previous injury led to relative risks ranging from 2.88 to 9.41 (11). However, inconsistency exists about the influence of motor performance (MP) on injury risk in children (11, 12, 26, 33, 39). Good performance in MP tests were in some studies negatively associated to risk of traumatic injury (11, 24, 33, 39), while other studies showed positive associations (6, 33) or no association (12, 26).

In adults, decreased balance, measured as length or the velocity of postural sway on a force platform, is recognised as a significant intrinsic risk factor of traumatic ankle injury and re-injury (27, 37). To our knowledge, examining sway as a risk factor of injury in a population of children 8- to 14-years-old has not yet been done.

Summative, lower extremity injuries are the most frequent injuries in children. The influence of MP on lower extremity injury risk in children is inconsistent, and the influence of balance on injury risk has not been investigated in children. The objective was to examine whether MP tests, including balance, can predict lower extremity injuries, traumatic as well as overuse, in children in general.

Materials and methods

This study was part of "the Childhood Health, Activity and Motor Performance School Study Denmark" (CHAMPS Study-DK) situated in the municipality of Svendborg, Denmark (38). At baseline in March 2012, 1244 participants aged 8- to 14-years-old were tested. The participants were followed consecutively for up to 15 months. Participants attended 10 public schools, four of which offered the participants two physical education lessons per week, and six of which offered the participants six physical education lessons per week. The selection of schools and sample size calculation have been described in detail previously (38).

Motor performance

The MP tests were carried out by clinicians during March 2012 in school gyms. The clinicians were thoroughly instructed in all test procedures during two full days of practice that included standardized calibration of the equipment, and measurement and instruction procedures.

Baseline tests of MP included

- Vertical jump test corresponding to Abalakow's vertical jump test (21). Best of three trials. If third jump performance was highest, participants continued trials until the last trial did not increase performance. This is a proxy for lower body muscular strength in youth (5) measured as jumping height in cm.
- Short shuttle run test from the Eurofit test battery (1). Participants should run five laps on a 5m lane. This is a measure of agility, measured by stopwatch in seconds. The command to start the test was "1,2,3-go".
- Prone bridge. Participants kept prone static position on elbows and toes until fatigue defined by touching the floor with other points than elbows and feet. This is a measure of static core stability, measured in seconds. Participants were encouraged to keep a straight-line position during the test.
- Side bridge. Participants kept side bridge position on elbow (non-dominant arm, defined as the arm not used for throwing a ball) and feet until fatigue, defined by touching the floor with other points than elbow and feet. This is a measure of

static core stability, measured in seconds. Participants were encouraged to keep a straight-line position during the test.

- Single leg hop for distance on the dominant and non-dominant leg. Participants jumped as far as possible on one leg. Best of three trials was recorded (or until levelling off). This is a measure of functional capacity of the lower extremity (31, 34), measured in cm.
- The Andersen test. A test of cardiorespiratory fitness (2). The test is an intermittent running test, running as far as possible back and forth between two lines 20m apart. The participants run for 15 seconds, have a break for 15 seconds, run for 15 seconds and so on for ten minutes. The result is measured in meters
- Balance tests, measured as postural sway on Nintendo Wii board, quantified as Centre of Pressure path Length (COPL) in cm. Four static balance tests were included: (1) Bilateral stance with eyes open, (2) unilateral stance with eyes open on the dominant and (3) non-dominant leg, and (4) bilateral stance with eyes closed. Participants were bare-footed. The dominant leg was defined as the leg for kicking. The median value of the COPL from three successful trials in each of the four different tests was chosen for analysis, as the median value has satisfactory concurrent validity when compared to a laboratory platform (22). Shorter COPL was interpreted as superior to longer COPL.

Test-retest reliability for the tests of balance, single leg hop for distance, vertical jump and short shuttle run presented Intraclass Correlation Coefficients (ICC) or Concordance Correlation Coefficients ranging between 0.76-0.98 (22, 30, 31). Test-retest reliability of the prone bridge test and side bridge test were examined in pilot projects with ICC ranging from 0.92-1.00 (14).

Anthropometrics

Weight was measured electronically to the nearest 0.1 kg (Tanita BWB-800S, Tanita Corporation, Tokyo, Japan), height to the nearest 0.5 cm using a portable stadiometer (SECA 214, Seca Corporation, Hannover, MD). Pubertal stage was assessed by self-assessment questionnaire (10) analyzed as a categorical variable (pubertal stage 1= pre pubertal, Tanner stage 2, 3 & 4=pubertal, 5=finished puberty). Self assessment of pubertal stage in adolescents has been reported to be reliable and valid (25).

Registration of complaints and sports participation

Information of complaints and organised sports participation were collected by weekly mobile phone text messages, using the SMS-track version 2.1 (New Agenda Solutions, SMS-Track ApS, Esbjerg, Denmark). To indicate complaints, the parents were asked: "Has (the child's name) had any pain during the last week?" with possible answers of 1=neck, back or low back; 2= shoulder, arm or hand; 3= hip, leg or foot; or 4=no, my child has not had any pain.

To indicate sports participation per week the parents were asked: "How many times did (the child's name) engage in sports during the last week?" (0=none, 1=once, 2=twice, 3=three times, …… or 8=more than 7 times). Thus, this was a measure of the participation in organised sports during leisure time.

The questions of complaints and sports participation were sent once a week (Sundays) and answers were automatically registered in a database. In case of non-correct values (e.g. a text instead of a number) the parents were contacted to get a correct answer.

A reminding text message was sent to the parents within 48 hours and 96 hours if no answer was registered. Previous studies have shown a high response rate of the SMS-track (18, 29).

Registration of injuries

In case of complaints, a telephone interview with the parents was performed. This way the children in need for further physical examination were identified, and physiotherapists and chiropractors examined and diagnosed the children in a mobile clinic by visiting each school once every 14 days. The injuries were registered by the ICD-10 system for diagnostic specifications, and only the complaints that lead to an ICD-10 diagnosis were included in the analyses. The injuries were collected from 1st of April 2012 until 30th of June 2013.

Ethics

Ethical approval was obtained for the CHAMPS-Study DK (project ID S-20080047). The study conforms with the declaration of Helsinki (36), and all parents gave their written informed consent for their child to participate in the study. Before the test sessions and clinical examinations each child gave verbal assent to participation.

Statistics

Descriptive statistics of individual characteristics and performance characteristics at baseline are presented as means ±SD, and range.

To model count variables with a possibility of excessive zeroes, we examined whether the zero-inflated negative binomial model, the zero-inflated poisson regression, the poisson regression or the negative binomial regression produced the best model fit of the data. These models allow the participants to be presented with more than one injury, and the effect of explanatory variables and covariates were examined, along with modelling the risk of getting an injury and the number of injuries. All analyses were checked for model fit using difference between predicted and observed counts of injuries and the Vuong test statistics with the Bayesian Information Criterion correction (8).

The outcome variables were total injuries in the lower extremity, injuries in the knee region and injuries in the ankle and foot region for both traumatic and overuse injuries. The variable total injuries in the lower extremity was not equal to the sum of ankle, foot and knee injuries, as all injuries in the lower extremity were not located in these regions.

Analyses were performed on standardized measures. Coefficients were interpreted as Incidence Rate Ratio (IRR) by IRR= exp (1SD* coefficient) (35). Analyses were all adjusted for sports participation (mean sports participation per week), age, body mass index (BMI), pubertal stage, sex and school type, since the amount of physical education lessons differed between schools (38). Analyses were performed with and without adjustment for previous injury. Previous injury was defined as previous traumatic ankle injury or traumatic knee injury in a period of 12 months before baseline. As inclusion criteria, the parents of the participants had to answer at least 49 weeks (80%) of the possible 62 weekly SMS-track questions. The statistical software Stata® (version 13.1, StataCorp, College Station, Texas, USA) was used for analyses. Significance level was set at $p \leq 0.05$.

Results

The inclusion criteria that the parents of the participants had to answer at least 49 weeks (80%) of the possible 62 weekly SMS-track questions led to exclusion of 13% of the participants. This resulted in 1084 participants in the analyses (mean age 11.2 years, 48% males). Only age differed between the included and the excluded participants (11.2 years versus 11.5 years). Individual and motor performance characteristics are presented in Table 1. A total of 874 injuries in the lower extremity were registered in the follow up period (651 overuse injuries and 223 traumatic injuries), with ankle sprains as the most common traumatic injury and growth related overuse knee injury (Mb. Osgood Schlatter or Mb. Sinding Larsen Johansson) as the most common overuse injury (Table 2).

Traumatic injuries

The results in Table 3 and Table 4 present the IRR when changing the MP measure 1 SD.

The analyses not adjusted for previous injury showed significant results in three of four sway measures for traumatic injuries in total (IRR 1.10-1.13), and similar for traumatic injuries in the foot and ankle region (IRR 1.14-1.15) reflecting that poor sway performance (longer COPL) increased injury risk (Table 3). When adjusting for previous injury, two of the four different sway measures remained significant risk factors for traumatic injuries and foot and ankle injuries, respectively, showing that longer COPL increased the risk of injuries (sway in bilateral stance, open eyes IRR=1.06, unilateral stance on non-dominant leg IRR=1.09) (Table 3). For the remaining sway tests the association to total traumatic injuries, foot and ankle injuries and knee injuries, respectively, were all pointing in the same direction meaning the longer the sway, the larger IRR, but being statistically borderline significant or non-significant (Table 3).

Good performance in single leg hop for distance (dominant leg) was protective of traumatic injuries of the knee both in the unadjusted model (IRR=0.66), and in the model adjusted for previous injury (IRR=0.68), indicating longer jump to decrease knee injury risk.

Good performance in prone bridge, side bridge and vertical jump increased the risk of traumatic injuries of the foot and ankle region significantly in the unadjusted model (IRR 1.12-1.16), indicating better performance to increase total injury risk and foot and ankle injury risk. Adjusting the model for previous injury led to borderline significant results for prone and side bridge, whereas the result for vertical jump did not remain significant. Previous injury was significantly related to all outcomes.

Overuse injuries

Poor performance in shuttle run (long time to finish shuttle run) (IRR=1.18) and good performance in prone bridge (IRR=1.09) significantly increased the risk of total overuse injuries and good performance in side bridge was borderline significantly related to in jury risk (IRR=1.07)(Table 4). In the knee region, good performance in prone bridge (IRR=1.16) and side bridge (IRR=1.12) significantly increased the risk of overuse injuries, whereas poor performance in shuttle run was borderline significantly related to injury risk of the knee. Of the sway tests only sway in bilateral stance with closed eyes was significantly related to the risk of overuse injuries. Results indicated that poor balance performance (longer COPL) significantly increased the risk of sustaining an ankle overuse injury (IRR=1.65).

Several covariates, in particular sports participation, age and gender (male) were significantly and positively associated to sustaining injuries in the foot region (Table 4).

Discussion

The main findings were that poor balance (longer sway) increased risk for traumatic injuries. In particular, most sway measures were significantly related to traumatic ankle injury. The remaining results on balance (the analyses of injury risk in the knee region and lower extremity injuries in total) pointed in the same direction of increased injury risk, with increasing COPL. Furthermore, increased functional capacity (longer performance in single leg hop for distance) significantly decreased the risk of traumatic injuries (table 3).

For overuse injuries a poor performance in shuttle run, and good performance in side bridge and prone bridge indicated an increased risk of total lower extremity injuries and knee injuries. In addition, poor performance in bilateral sway with eyes closed indicated an increased injury risk in the knee region.

Traumatic injuries

In both adjusted and un-adjusted analyses the results showed that bilateral sway tests and unilateral sway tests were significant predictors of traumatic injury, longer sway measures increasing the risk of traumatic injury. This result is supportive of previous studies on the relation between balance and injuries in adult populations (37, 39) examining risk factors of traumatic injuries of the ankle joint, primarily sprains. Thus, the results of the current study supports the hypothesis that an adequate postural control is important in relation to injury prevention in youth, in particular in the ankle region. The results of sway analyses related to the knee region were borderline significant or non-significant, but pointing in the same direction of the longer the sway, the larger IRR, as for the other groups of analyses. This could be related to the relatively few traumatic injuries in the knee region compared to the more frequent traumatic injury in the ankle region, thus, it could suggest a type 2 error (Table 2). The reason for the non-significant results related to sway performance on the dominant leg is unknown. However, it could relate to large differences in sway performance from sway test to sway test as shown in a recent study (22) but with satisfactory reliability for both bilateral and unilateral tests (CCC 0.76-0.86). In this study, sway measures in children were affected by large intra subject variability and large minimal detectable change of especially the one-legged tests. This could possibly explain and perhaps have an effect on the estimates and the significance.

To reflect the clinical impact of changing the predictors we chose to present the results as IRR when exposure variables changed by 1SD. In example, if IRR =1.09 (Table 3) the risk of traumatic injury of the ankle increases by 9% if COPL increases by 1SD. For traumatic injuries in the ankle region a change in the measures of bilateral sway with closed eyes by 1SD equivalents 1.3 cm excessive sway per second. This means that if sway performance increases with 1.3cm per second, the risk of ankle injury will increase with 8%.

Single leg hop for distance was negatively associated to the risk of traumatic knee injury, suggesting that good performance in hop is protective of injuries. The single leg hop for distance is suggested to measure the functional capacity of the lower extremity as it measures a combination of power, strength, proprioception, balance and coordination (3, 34). Thus, this finding could indicate, that these abilities are important to avoid a traumatic knee injury, which is in line with previous studies on adults (17).

Cardiorespiratory fitness (the Andersen test) was not associated with the risk of traumatic injury. This result is different from previous studies in adults showing low cardiorespiratory fitness to be associated with a higher risk of traumatic injuries (6, 11, 12, 39). A possible explanation for this could be that children maybe more likely than adults to take a break during exhaustion, instead of continuing competition. However, as we do not know if the performance in our population is different from the performance in the general population, this could also be a possible explanation that cardiorespiratory fitness is not related to injury risk.

When adjusting for previous injuries, the results of the analyses of vertical jump, prone and side bridge went from being significant to become borderline (prone and side bridge) or non-significant (vertical jump height). The two core stability measures indicated high skill-level to be a risk factor for traumatic injury only in the unadjusted analyses. But both adjusted and un-adjusted results supported what previous studies also found, that high skill-level in general is positively associated with the risk of ankle sprains in adults (soccer players) (39) or injuries in general in youth females (soccer players) (33). Therefore, the results cannot be dismissed. A hypothetical explanation could be that high skill-level is a risk factor due to the higher volume and intensity of play with potentially also higher exposure to tackles and foul play. That is, high skill level in power performances and core stability could be related to a high-risk behaviour (many hours of sport and high competitive behaviour) leading to higher risk of injuries. However, these factors were not examined in the current study.

The results showed that if the participants had an injury before the FMP tests, the injury should be adjusted for, as previous injury was a confounder. But as we are not aware of the performance of the participants before their first injury, we cannot establish the true causality. Thus, from our results it is not possible to determine, if the first time an injury occurs relate to poor performance or e.g. a congenital frailty in the individual participant.

Summarizing, poor performance (sway) and good performance (core stability and vertical jump) increased the risk of traumatic injury, while good performance in single leg hop for distance protected against traumatic injuries. The reason for the different directions of the estimates is not clear, but as the tests measure different components of motor performance, a possible explanation could be that single leg hop for distance and postural sway expresses some components, e.g. coordination and neuromuscular control components, and the vertical jump, prone bridge and side bridge tests expressing other components, e.g. strength, power or endurance components.

Overuse injuries

The result of a single sway analysis pointed in the same direction as for traumatic injuries, poor balance (longer COPL in bilateral stance with eyes closed) increased the risk of overuse ankle injuries. However, this result may be a chance finding, since the direction of the results of the remaining sway tests were generally inconsistent.

High skill-level in shuttle run, prone bridge and side-bridge pointed in the direction of the better the performance, the higher risk of overuse injuries. The finding, that children with the highest levels of motor performance are more likely to have overuse injuries could be explained by the hypothesis that children with high levels of MP are also the most active children as reported by Larsen and colleagues (23). Thus exposing themselves more often and for longer duration in physical activities and leisure time sports increasing the load on the musculoskeletal system. This explanantion follows the theory that physeal stress injuries are thought to develop when repetitive loading of the extremity disrupts metaphyseal perfusion (9). Furthermore, high-skilled and low-skilled sports participants could be different in behaviour while performing sports. The high-skilled sports participants may have a higher frequency of high-load movements such as acceleration, deceleration or high impact landings in e.g. handball or tumbling gymnastics increasing the physiologic strain on the musculoskeletal system, especially the apophyses. This is for future research to examine.

Summarizing, increasing performance in core stability increased the risk of overuse injuries as did decreasing performance in shuttle run. There was one significant result showing that poor performance in sway increased the risk of overuse injury, as would normally be expected. As the remaining estimates did not indicate the same relationship between sway and risk of injury, more studies are needed to confirm this result. Some of the implications of this study are, that researchers and clinicians should be very careful when trying to use performance tests for screening or prediction of injuries. It is important to distinguish between different aspects of motor performance e.g. power, balance or neuromuscular control. Furthermore, it is suggested to include information on behaviour in sports and leisure time of the participants.

Limitations

The analyses were adjusted for sports participation by the mean of sport participation per week throughout the follow up period. This measure does not reflect the degree of sports participation in the week close to the current injury and might affect especially the results related to overuse injuries, as these are more sensitive to the amount of physical activity close to the injury event. Furthermore, type of sport and intensity during sports could be important extrinsic risk factors, which were not adjusted for.

Whether the traumatic injuries occurred as a result of contact with another player, or as a result of physical stress, such as acceleration or deceleration, was not always reported by parents and children. Thus, the injury mechanism was not precise and therefore not used as discrimination. Since it is not known whether the injury mechanism influences the association between the exposure and the outcome, we do not consider this to blur our data. The injury mechanism may however, be recognized as a confounder

In the present study all participating clinicians were very thoroughly instructed and practiced all tests as performed in the test-rest studies. Further, pilot studies on children in the same age-range as the participants in the CHAMPS Study-DK secured sufficient testing quality, and therefore we believe the tests were performed as they should. Using the single leg hop for distance as a test in a child population is discussable, as the test is developed to use in a population of adults with restricted knee function (34). However, although the test is reliable and used in several studies (16) our finding is limited by the fact, that the test has not been validated in a population of children.

Strengths

This study is the first large-scaled study to include the use of a reliable and valid field measure of sway performance, and to examine MP tests as being predictors for both traumatic and/or overuse injuries. Furthermore, the large sample size, the relatively long follow-up period of 15 months with repeated and detailed registrations of injuries, using clinicians to register injuries by the ICD-10 registration system are considerable strengths of the study. Using a momentary assessment-like method, the SMS-track, throughout the follow-up period limited the risk of recall bias, and allowed us to have a very detailed registration of traumatic and overuse injuries, including the possibility of adjusting for previous injury.

Conclusion

Poor sway performance was a consistent predictor of injuries in children, in particular for traumatic ankle injuries. Good motor performance (core stability, vertical jump, shuttle run) was positively associated with traumatic and overuse injuries, and negatively (single leg hop) associated with traumatic injuries, indicating different influence of the tests in relation to injury risk. Previous injury was a confounder affecting the effect size and the significance. More studies are needed to consolidate the findings, to clarify the influence of different performance tests on different types of injuries and to examine the influence of behaviour in relation to injury risk.

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Conflicts of Interests

The authors have no professional relationships with companies or manufacturers who will benefit from the results of the current study. The results of the current study do not constitute endorsement by the American College of Sports Medicine.

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Table 1. Demographics and motor performance characteristics ((mean; SD; range).

	n	Mean (SD)	Range
Age (years)	1073	11.2 (1.4)	8 - 14
Height (cm)	1084	152.0 (10.8)	126 - 186
Weight (kg)	1080	42.3 (10.4)	22.9 - 97.7
Agility run (sec)	1054	21.9 (2.2)	14.2 - 31.7
Prone bridge (sec)	1067	89.0 (73.7)	5 - 962
Side bridge (sec)	1063	52.4 (32.8)	4 - 394
Andersen test# (m)	910	1010.9 (105.7)	680 - 1463
Single leg hop for distance, dominant leg (cm)	1036	102.9 (23.6)	28 - 194
Single leg hop for distance, non-dominant leg (cm)	1033	102.1 (24.7)	33 - 196
Vertical jump (cm)	1075	33.5 (6.5)	15 - 72
Sway bilateral stance, EO (cm/30 sec (COPL))	931	73.7 (37.5)	35.5-521.3
Sway, dominant leg , EO (cm/30 sec (COPL))	943	153.6 (63.9)	68.7-979.6
Sway non-dominant leg, EO (cm/30 sec (COPL))	942	152.3 (68.6)	50.7- 910.7
Sway, bilateral stance, EC (cm/30 sec (COPL))	929	103.7 (41.9)	50.9- 697.1
Mean sports participation (times/week)	1067	1.7 (1.2)	0 - 7.1

n =number of participants, SD= standard deviation, sec=seconds, EO=eyes open, EC= eyes closed, bilat= bilateral, dom=dominant, non-dom=non-dominant, #=only Andersen tests> 600m

Table 2 Number of injuries and diagnoses classified according to the International Classification of Diseases (ICD-10) in total, region specific and by type of injury.

	Diagnosis	ICD-10	n	Knee region n (%)	Ankle region n (%)
Traumatic injuries	Sprains, knee	S83, S834, S835B, S836, S836C	29	29 (100)	
	Sprains, ankle	S934, S934A, S934B	86		86 (100)
	Fractures lower extremity	S822, S925, S924, S826, S923E, S821	9	0 (0)	7 (78)
	Contusion lower extremity	S801, S700, S800, S903, S900,	45	23 (51)	19 (42)
	Sprains, other (e.g. toe)	T132, S935, S731	15	0 (0)	4 (27)
	Injury of muscle, fascia, tendon in lower extremity	S760, S761, S762, S763, S861	8	2 (25)	2 (25)
	Other traumatic injuries	(e.g. T933A)	31	2 (6)	6 (19)
Total traumatic injuries*			223	56 (25)	124 (56)
Overuse Injuries	Severs disease	M928	135		135 (100)
	Unspecific soft tissue disorder related to use/pressure	M709	82	15 (18)	9 (11)
	Osgood Schlatters or Sinding Larsen Johansens disease	M924, M925	205	205 (100)	
	Fascitis plantaris	M722	23		23 (100)
	Other patella-femoral conditions	M222	46	46 (100)	
	Tendinitis lower extremity, total	M766, M776, M761, M765, M768B, M706A, M779A	110	18 (16)	54 (49)
	Other overuse injuries	(e.g. M869B, , M626)	50	14 (28)	4 (8)
Total overuse Injuries*			651	298 (46)	225 (35)

* = the total number of injuries is not equal to the sum of ankle and knee injuries as not all injuries were in the ankle or knee region.

Table 3. Risk of traumatic injuries. Results of regression analysis of standardized measures showing Incidence Rate Ratios (IRR) with 1 Standard Deviation change in performance.

	Total traumatic injuries, lower extremity		Knee injuries		Foot/ankle injuries	
	Standardized IRR[a] unadjusted (95% CI)	*Standardised IRR[a], adjusted (95% CI)*	*Standardized IRR[a] unadjusted (95% CI)*	*Standardised IRR[a], adjusted (95% CI)*	*Standardized IRR[a] unadjusted (95% CI)*	*Standardised IRR[a], adjusted (95% CI)*
Sway bilateral stance, EO	1.10 [*b]	1.06 [* bde]	1.05 [b]	1.06 [be]	1.14 [*bd]	1.09 [* bde]
	(1.04 to 1.17)	(1.001 to 1.13)	(0.88 to 1.27)	(0.89 to 1.26)	(1.06 to 1.23)	(1.01 to 1.17)
Sway, dominant leg, EO	1.05 [bd]	1.04 [bde]	1.08 [b]	1.08 [e]	1.06 [bd]	1.04 [bde]
	(0.92 to 1.20)	(0.94 to 1.15)	(0.92 to 1.27)	(0.93 to 1.27)	(0.89 to 1.27)	(0.91 to 1.20)
Sway non-dominant leg, EO	1.13 [* bd]	1.09 [* bde]	1.14 [#]	1.14[#e]	1.15 [*bd]	1.09 [* bde]
	(1.05 to 1.23)	(1.02 to 1.17)	(0.98 to 1.31)	(0.99 to 1.32)	(1.04 to 1.27)	(1.01 to 1.17)
Sway, bilateral stance, EC	1.10 [* bd]	1.06 [# bde]	1.07	1.08 [be]	1.14 [*bd]	1.08 [# bde]
	(1.01 to 1.20)	(0.99 to 1.14)	(0.91 to 1.27)	(0.91 to 1.28)	(1.03 to 1.26)	(0.99 to 1.18)
Agility run	1.03 [bde]	1.04 [bde]	0.98	0.99 [e]	0.97 [cd]	0.98 [bde]
	(0.87 to 1.22)	(0.89 to 1.22)	(0.73 to 1.31)	(0.74 to 1.31)	(0.81 to 1.16)	(0.82 to 1.16)
Prone bridge	1.15 [* bd]	1.11 [# bde]	1.07	1.06 [e]	1.16 [*bd]	1.09 [bde]
	(1.04 to 1.27)	(0.98 to 1.25)	(0.90 to 1.27)	(0.89 to 1.27)	(1.03 to 1.29)	(0.97 to 1.22)
Side bridge	1.08 [bd]	1.04 [bde]	0.84	0.83 [e]	1.14 [*bd]	1.08 [# bde]
	(0.96 to 1.21)	(0.94 to 1.15)	(0.59 to 1.20)	(0.59 to 1.18)	(1.02 to 1.28)	(0.98 to 1.17)
Single leg hop, dominant leg	0.95 [b]	0.96 [be]	0.66 [*b]	0.68[* be]	1.06 [bd]	1.08 [bde]
	(0.78 to 1.16)	(0.79 to 1.17)	(0.51 to 0.84)	(0.53 to 0.87)	(0.84 to 1.34)	(0.85 to 1.37)
Single leg hop, non-dominant leg	1.06 [bd]	1.05 [bde]	0.85	0.87 [e]	1.07 [bd]	1.05 [bde]
	(0.88 to 1.27)	(0.87 to 1.26)	(0.59 to 1.21)	(0.60 to 1.25)	(0.88 to 1.30)	(0.87 to 1.26)
Andersen	1.06 [b]	1.05 [be]	0.95	0.92 [e]	1.10 [b]	1.08 [be]
	(0.84 to 1.34)	(0.83 to 1.33)	(0.60 to 1.50)	(0.61 to 1.39)	(0.84 to 1.46)	(0.82 to 1.43)
Vertical jump	1.08 [#bd]	1.05 [bde]	1.03	1.04 [e]	1.12 [*bd]	1.08 [bde]
	(0.99 to 1.18)	(0.97 to 1.13)	(0.85 to 1.25)	(0.86 to 1.26)	(1.01 to 1.25)	(0.98 to 1.18)

Analyses are adjusted for sports participation, age, sex, body mass index (BMI) and school type. Unadjusted analyses are not adjusted for previous injury, adjusted analyses are adjusted for previous injury.

CI=Confidence Interval, EO= Eyes Open, EC= Eyes Closed

a = IRR calculated as exp(1*coefficient)

b = sports participation significant, c= age significant d=BMI significant e=previous injury significant

* = p≤0.05

= 0.05≤p≤0.1

Table 4. Risk of overuse injuries. Results of regression analysis of standardized measures showing Incidence Rate Ratios (IRR) with 1 Standard Deviation change in performance.

	Total overuse injuries, lower extremity	Knee, overuse injuries	Ankle /foot, overuse injuries
	IRR[a], standardised (95% CI)	*IRR[a], standardised (95% CI)*	*IRR[a], standardised (95% CI)*
Sway bilateral stance EO	0.98 [b] (0.90 to 1.08)	0.95 [b] (0.84 to1.07)	0.90 [bec] (0.76 to 1.06)
Sway, dominant Leg, EO	0.98 [b] (0.89 to 1.08)	0.96 [b] (0.86 to 1.08)	0.93 [bec] (0.78 to 1.10)
Sway non-dominant leg, EO	1.01 [b] (0.93 to 1.10)	1.01 [b] (0.89 to 1.14)	0.94 [bec] (0.75 to 1.18)
Sway, bilateral stance, EC	1.02 [b] (0.95 to 1.10)	0.99 [b] (0.91 to 1.09)	1.65 [*bd] (1.24 to 2.19)
Shuttle run	1.18 [*bc] (1.07 to 1.31)	1.15 [#] (0.98 to 1.34)	1.10 [bc] (0.92 to 1.32)
Prone bridge	1.09 [*b] (1.01 to 1.17)	1.16 [*] (1.07 to 1.26)	0.99 [bec] (0.90 to 1.10)
Side bridge	1.07 [#b] (1.00 to 1.15)	1.12 [*bc] (1.03 to 1.24)	1.05 [bec] (0.93 to 1.18)
Single leg hop for distance, dominant leg	0.99 [b] (0.87 to 1.11)	0.89 [b] (0.76 to 1.05)	1.06 [bec] (0.90 to 1.24)
Single leg hop for distance, non-dominant leg	1.00 [b] (0.89 to 1.13)	0.94 (0.80 to 1.11)	0.97 [bec] (0.82 to 1.14)
Andersen	1.08 [b] (0.90 to 1.30)	1.07 (0.84 to 1.38)	0.98 [bec] (0.78 to 1.22)
Vertical jump	0.95 [b] (0.86 to 1.05)	0.90 [b] (0.76 to 1.07)	0.86 [bec#] (0.72 to 1.03)

Analyses are adjusted for sports participation, age, sex, body mass index (BMI) and school type.
CI=Confidence Interval, EO= Eyes Open, EC= Eyes Closed
a=IRR calculated as exp(1*coeffificient)
b=sportsparticipation significant, , c=age significant d=tanner significant e= gender significant
*=p≤0.05
#=0.05≤p≤0.1