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ASSOCIATION BETWEEN LOWER EXTREMITY MUSCLE STRENGTH AND ACUTE ANKLE INJURY IN YOUNG TEAM-SPORTS ATHLETES

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STATEMENT OF FINANCIAL DISCLOSURE AND CONFLICT OF INTEREST

This study was financially supported by the Finnish Ministry of Education and Culture and the Competitive State Research Financing of the Expert Responsibility Area of Tampere University Hospital (Grants 9N053, 9S047, 9T046, 9U044). The authors declare that the results of the study are presented clearly, honestly, and without fabrication, falcification, or inappropriate data manipulation, and statement that results of the present study do not constitute endorsement by ACSM. The authors declare that there is no conflict of interest regarding the publication of this paper.

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ABSTRACT

Objective: To investigate selected lower extremity muscle strength variables as potential risk factors for an acute ankle injury in young athletes.

Design: Cohort study; Level of evidence, 3.

Methods: A total of 188 young (≤ 21) male and 174 female basketball and floorball players participated in muscular strength tests and were followed for an acute ankle injury up to three years. The tests were 1RM leg press strength, maximal concentric isokinetic quadriceps and hamstrings strength (60°/s) and maximal isometric hip abductor strength.

Results: In males, greater 1RM leg press strength and maximal quadriceps strength increased the risk of any type of acute ankle injury (HR for 1 SD increase, 1.63 [95% CI, 1.12–2.39]; P = 0.01 and 1.43 [95% CI, 1.01–2.01]; P = 0.04, respectively). In females, greater 1RM leg press strength and difference between legs in maximal hip abduction strength increased the risk of acute non-contact ankle injury (HR for 1 SD increase, 1.44 [95% CI, 1.03–2.02]; P = 0.03 and 1.44 [95% CI, 1.03–2.00]; P = 0.03, respectively). However, ROC curve analyses showed AUC:s of 0.57-0.64 indicating “fail” to “poor” combined sensitivity and specifity of these tests.

Conclusion: Muscular strength and its leg asymmetry was associated with acute ankle injury risk in youth athletes. However, none of these strength tests can be used alone as screening tools for future injuries.

Keywords: SPORT INJURY; INJURY RISK; YOUTH SPORT

INTRODUCTION

Incidence of ankle injuries is high in youth team sports.[17, 18] Lateral ankle sprains are observed most frequently.[8] Ankle sprains can lead to a marked loss of practicing and playing time[4] and often evolve persistent pain, weakness and chronic instability possibly resulting in lower sport activity levels or even change of sports.[1]

Identifying risk factors that are modifiable and clinically easy to test are essential before planning injury prevention programs.[2] The role of lower extremity (LE) muscle strength as a risk factor for sport injury is controversial. Lower quadriceps and hamstrings strength or strength imbalances between these muscles have shown to increase the risk of knee ligament sprains and hamstring strains[6, 15, 23, 25] although contrary results also exist.[3, 16] Lower hip abduction strength has been associated with an increased risk of ankle injury,[10, 21] whereas other studies did not find such association.[7, 14, 16]

Most of the studies exploring the association between LE muscle strength and sports injury have concerned mainly adult or professional athletes[3, 16, 21, 24] or focused on knee or ACL injuries.[12, 15, 22] Only few studies have investigated the association between LE muscle strength and ankle injury in youth athletes. One study found that lower maximal hip extension strength was an independent risk factor for lateral ankle sprain in young male soccer players but no associations were reported between maximal hip flexion, abduction, adduction or rotational strengths and ankle sprains.[7] Another study neither found associations between maximal hip flexion, abduction or adduction strength and non-contact ankle sprains in a group of high-school athletes.[14] However, only hip strength variables were measured in these studies.

The purpose of this study was thus to investigate selected LE muscle strength variables as potential risk factors for an acute ankle injury in young male and female team-sport athletes. We hypothesized that lower muscle strength increases the risk of these injuries.

METHODS

Study design and participants

This study is part of the Predictors of Lower Extremity Injuries in Team Sports (PROFITS) study.[19] The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Pirkanmaa Hospital District, Tampere, Finland (ETL-code R10169). The participants signed a written informed consent before entering the study (including parental consent for participants under the age of 18).

Junior-aged (≤21 yrs) basketball and floorball players were recruited from 9 basketball and 9 floorball teams from 6 sports clubs from Tampere city district. All players played at the two highest junior or adult league levels. Inclusion criteria were: 21 years of age or younger, official team member and free from injury at baseline. Athletes were considered injury-free if they did not report injuries at baseline questionnaire and they were able to fully participate in baseline tests. Altogether 214 male (102 basketball and 112 floorball) and 189 female (107 basketball and 82 floorball) players entered the study during the preseason (April-May) in 2011, 2012 or 2013. Each player completed a baseline questionnaire including questions about age, sex, previous injuries and playing level. Standing height (cm) and weight (kg) were recorded. The strength tests were maximal one-repetition (1RM) seated leg press strength, maximal concentric isokinetic quadriceps and hamstrings strength (60°/s) and maximal isometric hip abductor strength (**FIGURE 1**). The complete test protocols are described in detail as supplementary material (**APPENDIX 1**). After baseline tests, injury registration continued until the end of April 2014. A total of 190 male and 178 female players completed the tests. Two male and 4 female players were excluded from the analyses, because they were not official members of the participating teams leading to a total of 188 male and 174 female players in the final analysis (**FIGURE 2**).

Injury and exposure registration

During a follow-up period (May 2011–April 2014), all acute ankle injuries were registered with a structured questionnaire. Two study physicians were responsible for collecting the injury data. They contacted the teams once a week to check possible new injuries and after each injury reported, the injured player was interviewed by telephone using the questionnaire. Injury definition was modified from definition by Fuller and colleagues.[11] An injury was recorded if the player was unable to fully participate in matches or training during the next 24 hours. Only injuries which occurred in a teams' scheduled training sessions or matches were included in this study. The injuries were classified as contact (ie. direct contact or strike to the involved ankle) or non-contact (ie. no direct contact to the involved ankle).

During the follow-up, the coach of each team recorded players' participation in trainings and matches. Player attendance in a training session (yes/no), duration of a training session (h) and attendance in each period of a match (yes/no) were recorded individually on a team diary. The diaries were returned after each follow-up month and the individual monthly exposure time (h) were registered for all players.

Statistical analysis

Descriptive data are presented as the mean ± standard deviation (SD) or the median and interquartile range (IQR) depending on the normality of distribution of variables. An independent-samples *t* test was used to compare group differences for normally distributed variables and the Mann-Whitney *U* test for non-normally distributed variables. Depending on the distribution of the variables, Pearson's and Spearman's correlation coefficients were used to evaluate linear correlation between two variables. Injury incidences were calculated as the number of injuries per 1000 player-hours and reported with 95% CIs: ([*Incidence rate* – 1.96 * *Standard error of incidence rate*] * 1000 hours) to ([*Incidence rate* + 1.96 * *Standard error of incidence rate*] * 1000 hours). Results were calculated separately for male and female players and for all and non-contact acute ankle injuries. Recurrent injuries were included in incidence calculations.

Cox regression models were used to analyse strength variables. The models were generated using the player or the leg as a unit of analysis. The unit of analysis was defined according to strength variable representing either the characteristic of the player or of the leg. The outcomes were a new acute (contact or non-contact) ankle injury and a new acute non-contact ankle injury. The models were generated separately for males and females. Exposure time (h) from the start of the follow-up until the first injury or the end of the follow-up were included in the models. The exposure time of a month when an injury occurred were estimated by dividing the days from the beginning of the month to the injury date by all days of the month and then by multiplying the result by the registered total (playing and training) hours of the month. Sports club was included in all models as random effect and the leg in the models using it as the unit of analysis. Unadjusted and adjusted models with predefined adjustement factors were made for strength variables. The adjustement factors that might mostly influence to the risk of ankle injury were selected in the following order: previous acute ankle injury, age, height, sport and playing at adult level. These adjustement factors were included in the models according to the amount of injuries in each model, using estimation of 10 injuries needed per included variable.[20] In the models using the player as the unit of analysis, previous injuries of ipsilateral or contralateral side were included, and in the models using the leg as a unit analysis, only injuries of ipsilateral side were included.

Cox hazard ratios (HRs) per 1 SD increase with 95% CIs were calculated for each strength variable. P value < 0.05 were considered significant. A receiver operaiting characteristics (ROC) curve analysis were calculated to assess the combined sensitivity and specifity of a test in cases where significant associations between the strength variable and the outcome were found. The test was defined as “excellent” (0.90–1.00), “good” (0.80–0.89), “fair” (0.70–0.79), “poor” (0.60–0.69) and “fail” (0.50–0.59). Statistical analyses were conducted in SPSS for Windows (v.20.0.0;

SPSS), except the regression models, which were conducted in R (v3.1.2; R Foundation for Statistical Computing).

RESULTS

Cohort baseline characteristics

Complete data were obtained from 188 (88%) male and 174 (92%) female players. The mean follow-up period was 1.3 ± 0.6 and 1.7 ± 0.6 years in males and females, respectively. Both male and female floorball players were significantly older compared with basketball players. Significant differences were also observed in BMI, playing and practicing hours and previous acute ankle injuries across sports and sexes (**TABLE 1**).

Injury characteristics

In males, a total of 43 new acute ankle injuries occurred in 38 players and 24 of these were non-contact injuries. In addition, 12 players had one or more re-injuries to the same ankle. Fortyone (95%) of all acute ankle injuries in males was diagnosed as lateral ankle sprains. The overall and non-contact ankle injury incidence for males was 0.9 (95% CI, 0.7–1.1) and 0.5 (95% CI, 0.3–0.7) injuries per 1000 player-hours, respectively.

In females, there were 62 new acute ankle injuries in 55 players and 44 occurred in non-contact situations. Twelve players had also one or more re-injuries to the same ankle. Fiftysix (90%) of all acute ankle injuries was diagnosed as lateral ankle sprains. The overall and non-contact ankle injury incidence for females was 1.3 (95% CI, 1.0–1.6) and 0.9 (95% CI, 0.7–1.1) injuries per 1000 player-hours, respectively.

Unadjusted group differences

In males, 1RM leg press strength (kg/kg) was 10 % greater in players who had any type of acute ankle injury (mean difference 0.3, P = 0.003) and 9 % greater who had acute non-contact ankle injury (mean difference 0.25, P = 0.04). In addition, maximal isokinetic quadriceps strength

(Nm/kg) was 7% greater in injured compared to uninjured legs in male players who suffered any type of acute ankle injury (mean difference 0.18, P = 0.01) (**APPENDIX 2**).

In females, 1RM leg press strength was 8% greater in players who suffered acute non-contact ankle injury (mean difference 0,19, P = 0.01) (**APPENDIX 3**).

Adjusted risk factor analyses

In males, greater 1RM leg press and maximal isokinetic quadriceps strength were associated with an increased risk of any type of acute ankle injury (HR for 1 SD increase, 1.63 [95% CI, 1.12–2.39]; P = 0.01 and 1.43 [95% CI, 1.01–2.01]; P = 0.04, respectively) (**TABLE 2**). However, receiver operating characteristic (ROC) curve analyses showed an area under the curve (AUC) of 0.64 for 1RM leg press and 0.62 for maximal isokinetic quadriceps strength test, indicating "poor" combined sensitivity and specifity of these tests. There was a moderate correlation ($r = 0.48$, $p < 0.001$) between age and 1RM leg press and weak correlation ($r = 0.36$, $p < 0.001$) between age and isokinetic quadriceps strength in male players.

In females, greater 1RM leg press strength and difference between legs in maximal hip abduction strength increased the risk of acute non-contact ankle injury (HR for 1 SD increase, 1.44 [95% CI, 1.03–2.02]; P = 0.03 and 1.44 [95% CI, 1.03–2.00]; P = 0.03, respectively) (**TABLE 2**). However, according to the ROC curve analysis, the combined sensitivity and specifity of the tests were "poor" and "fail" (AUC:s of 0.63 for 1 RM leg press strength test and 0.57 for strength difference between legs in hip abduction).

DISCUSSION

Lower extremity muscle strength and acute ankle injury in males

We found that stronger male players identified with greater 1RM leg press and maximal isokinetic quadriceps strength were at increased risk to get any type of acute ankle injury. Greater quadriceps strength has previously suggested to associate with the increased risk of hamstring strains,[9] but to our knowledge, not with ankle injuries in male athletes. It could be assumed, that older junior-aged male players are stronger and they practise and play more even in adult league teams thus being more time at risk to get an injury. However, we found no strong correlations between male players' age and 1RM leg press or maximal isokinetic quadriceps strength indicating that age alone is not sufficient enough to explain this finding. Nevertheless, stronger players might have been more mature and skilled otherwise. Strong players may also be able to run and change direction faster leading to greater mechanical forces and in this way the injury risk may increase. In addition, being strong does not necessarily mean that a player has a proper landing and direction change technique. Poor technique combined with greater muscle mass and higher speed may increase ligament loading and ankle injury risk in stronger players compared to weaker lightweighted players.

Powers et al[21] reported an association between lower maximal hip abduction strength and increased risk of non-contact lateral ankle sprain in a group of junior and adult male soccer players (aged 13-34 years). In the present study, such association was not found. However, the reported average body-mass normalized maximal hip abduction strength values were almost two times greater in Powers and colleagues[21] study compared to ours meaning that players in Powers et al[21] study might be considerably stronger at all, which might also have influenced the risk of ankle sprain as in the present study. Supporting findings of our study, McHugh and study group[14] reported that maximal hip abductor strength was not a predictor for non-contact lateral ankle sprain in a group of male and female high school athletes. De Ridder and colleagues[7] found also no association between maximal hip abduction strength and lateral ankle sprain in young male soccer players but reported that lower maximal hip extensor strength increased the risk of these injuries. Although we did not measure maximal hip extension strength, we would expect that greater, rather than lower, hip extension strength might have increased the risk of ankle sprain because greater 1RM leg press strength increased the risk of these injuries in the present study.

Lower extremity muscle strength and acute ankle injury in females

The findings concerning female players extend previous findings from a prospective Norwegian study in female elite soccer players. Nilstad et al[16] found also no association between maximal isokinetic quadriceps and hamstrings strength, HQ ratio or maximal hip abduction strength and any ankle injury. Although the players in the present study were considerably younger (15.4 years on average compared to 20.9 years in the Norwegian study) the selected muscle strength variables did not associate with ankle injury risk in females. In contrast to Nilstad and colleagues[16] study, we found that lower 1RM leg press strength increase the risk of acute non-contact ankle injury. Lower 1RM leg press strength has been found also to increase the risk of acute knee injury in young female athletes.[22]

We found that greater difference between legs in maximal hip abduction strength increased the risk of acute non-contact ankle injury in young female athletes. The mechanistic connection between this strength imbalance and non-contact ankle injury is unclear and it is possible that these female athletes also had strength imbalances in other LE or core muscles. The strength imbalance in hip abductors can also be a compensatory mechanism to inadequate or false kinetic patterns in athletic movements like landings, turnings and running, in which non-contact ankle injuries commonly occur.[27] Thus, this finding should be interpreted with caution.

Clinical implications

Although we found that stronger male and female athletes were at increased risk to get an acute ankle injury, it does not mean that LE strength excercises should be taken out of injury prevention programmes in young athetes. Correspondingly, we believe that young female athletes should not exclusively concentrate on to strengthen hip abductor muscles of the weaker leg. It should be noticed that we measured maximal muscle strength, but in neuromuscular injury prevention programs, muscle strength training usually contains exercises with low or no additional weights while concentrating on proper technique with gradually increasing volume and intensity.[13] Neuromuscular injury prevention programs including low- or body weigth strength exercises have shown to be effective in the prevention of acute and also overuse LE injuries in young male and female athletes.[5, 26, 28]

Regardless of significant associations between the muscle strength variables and ankle injury in our study, substantial overlap between the test results in injured and uninjured athletes existed leading “fail” to “poor” combined sensitivity and specifity for the strength tests meaning that the tests can correctly classify <70% of injured and uninjured athletes. Therefore, in clinical practice, the muscle strength tests as measured in the present study cannot be recommended alone as injury screening tools for acute ankle injury in young athletes.

Study strengths and limitations

This study had several strengths including the relatively long follow-up, large sample size and low drop-out rate. Also, prospectively collected injury and exposure data enabled the use of Cox regression models. In addition, in the statistical analyses, we used the player or the leg as a unit of analysis depending on the muscle strength variable. Moreover, the strength variables were measured in this study with standard and simple procedures easy to use in clinical practice.

This study also had limitations. Maximal isokinetic hamstring and quadriceps strengths were measured only with an angular velocity of 60°/s. It is obvious that much higher angular velocities are involved in knee motions and ankle injury situations in ball-sports. Also, maximal hip abduction strength could have been measured with the hip in flexion because in ankle injury situations the hip is probably slightly in flexion rather than in straight position. In addition, we did not repeat the strength measurements during the study and thus the strength values might change during the 3-year follow-up.

CONCLUSION

Our 3-year prospective study showed that greater 1RM leg press and maximal quadriceps strength increased the risk of any type of acute ankle injury in young male athletes while greater 1RM leg press strength and greater difference between legs in maximal hip abduction strength increased the risk of acute non-contact ankle injury in young female athletes. However, according to the ROC curve analysis, these strength variables as measured in the present study cannot be used alone as screening tools for acute ankle injury in young team-sport athletes.

KEY POINTS

Findings: Greater 1RM leg press strength and maximal quadriceps strength increased the risk of any type of acute ankle injury in young male athletes. Greater 1RM leg press strength and difference between legs in maximal hip abduction strength increased the risk of acute non-contact ankle injury in young female athletes. However, ROC curve analysis showed AUC:s of 0.57-0.64 indicating “fail” to “poor” combined sensitivity and specifity of these tests.

Implications: Maximal muscle strength tests as measured in the present study cannot be recommended as screening tools to identify young athletes who are at risk to get an acute ankle injury.

Caution: The results of the study can only be applied to young athletes and further studies are needed to evaluate the role of LE muscle strength risk factors for the risk of acute ankle injury in adult and professional athletes.

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TABLE 1, Demographic data, exposure times and ankle injury history in male (n = 188) and female (n = 174) players

	Male				Female			
	All (n = 188)	Basketball (n = 93)	Floorball (n = 95)	P- value	All (n = 174)	Basketball (n = 96)	Floorball (n = 78)	P- value
Age (y)[a]	16.0 ± 1.6	15.2 ± 1.6	16.8 ± 1.2	< 0.001	15.4 ± 2.0	14.6 ± 1.6	16.5 ± 1.9	< 0.001
Height (cm)[b]	178.6 ± 8.1	179.0 ± 9.6	178.2 ± 6.3	0.49	167.4 ± 6.2	168.2 ± 6.4	166.5 ± 5.7	0.08
Weight (kg)[b]	69.2 ± 10.9	68.6 ± 13.0	69.8 ± 8.3	0.44	61.0 ± 8.6	61.0 ± 9.5	61.1 ± 7.3	0.86
BMI, (kg/m^2)[b]	21.6 ± 2.7	21.3 ± 3.0	22.0 ± 2.3	0.04	21.7 ± 2.7	21.5 ± 2.8	22.0 ± 2.5	0.24
Playing experience (y)[b]	8.1 ± 3.1	7.4 ± 3.2	8.8 ± 2.8	0.001	6.3 ± 2.5	6.4 ± 2.5	6.2 ± 2.5	0.43
Match exposure (h)[c]	10.4 (10.0)	8.0 (6.3)	13.3 (8.6)	< 0.001	10.1 (16.4)	7.3 (8.8)	19.9 (25.5)	< 0.001
Training exposure (h)[c]	288.2 (228.8)	294.7 (178.5)	284.4 (276.8)	0.53	252.0 (342.9)	203.3 (123.4)	478.6 (424.6)	< 0.001
Total exposure (h)[c]	298.9 (238.5)	300.0 (181.8)	297.8 (279.7)	0.44	258.9 (365.1)	214.1 (124.6)	500.6 (456.7)	< 0.001
Previous acute ankle injury (n)[e]	108	61	47	0.03	99	53	46	0.62

[a]Age at the start of the follow-up. Values are presented as mean ± SD.

[b]Values are presented as mean ± SD.

[c]Values are presented as median (IQR).

[d]Values are presented as total number of injuries.

TABLE 2, Unadjusted and adjusted HR (per 1 SD increase) with 95% Cis for strength variables for ankle injuries in males and females[a]

	Male				Female			
	All ankle injuries		Non-contact ankle injuries		All ankle injuries		Non-contact ankle injuries	
	HR (95% CI)	Adjusted HR (95% CI)	HR (95% CI)	Adjusted HR (95% CI)	HR (95% CI)	Adjusted HR (95% CI)	HR (95% CI)	Adjusted HR (95% CI)
Player as a unit of analysis								
Leg press (kg/kg)[b]	**1.63 (1.17-2.27)**	**1.63 (1.12-2.39)** [e]	1.39 (0.93-2.09)	1.34 (0.89-2.01) [d]	1.23 (0.93-1.63)	1.32 (0.96-1.80) [h]	**1.38 (1.01-1.88)**	**1.44 (1.03-2.02)** [f]
Quadriceps between- leg difference (Nm)[c]	1.23 (0.87-1.74)	1.18 (0.83-1.67) [e]	1.44 (0.95-2.20)	1.39 (0.90-2.14) [d]	0.84 (0.59-1.18)	0.85 (0.62-1.16) [h]	0.85 (0.59-1.22)	0.86 (0.62-1.21) [f]
Hamstring between- leg difference (Nm)[c]	1.10 (0.82-1.48)	1.08 (0.80-1.47) [e]	0,69 (0.41-1.16)	0.67 (0.39-1.16) [d]	1.00 (0.76-1.30)	1.00 (0.77-1.31) [h]	0.97 (0.70-1.34)	0.97 (0.70-1.34) [f]
Hip abduction between- leg difference (kg)[c]	1.10 (0.79-1.52)	1.02 (0.73-1.43) [e]	1.28 (0.88-1.87)	1.23 (0.85-1.79) [d]	1.15 (0.88-1.50)	1.14 (0.87-1.49) [h]	**1.44 (1.05-1.98)**	**1.44 (1.03-2.00)** [f]
Leg as a unit of analysis								
Quadriceps (Nm/kg)[b]	**1.50 (1.10-2.06)**	**1.43 (1.01-2.01)** [f]	1.06 (0.70-1.60)	0.99 (0.65-1.52) [d]	0.88 (0.68-1.15)	0.88 (0.66-1.17) [i]	0.84 (0.61-1.14)	0.85 (0.61-1.18) [f]
Hamstrings (Nm/kg)[b]	1.13 (0.83-1.53)	1.04 (0.74-1.45) [f]	0.80 (0.52-1.22)	0.74 (0.48-1.14) [d]	0.91 (0.69-1.19)	0.90 (0.67-1.21) [i]	0.84 (0.61-1.17)	0.82 (0.58-1.17) [f]
HQ ratio (%)	**0.71 (0.51-0.99)**	0.72 (0.52-1.00) [f] 0.052	0.71 (0.46-1.09)	0.72 (0.47-1.10) [d]	1.02 (0.77-1.35)	1.02 (0.77-1.37) [i]	0.98 (0.71-1.36)	0.95 (0.67-1.33) [f]
Hip abduction (kg/kg)[b]	0.88 (0.63-1.24)	0.88 (0.62-1.24) [f]	1.02 (0.68-1.55)	1.04 (0.69-1.57) [d]	1.09 (0.84-1.42)	1.10 (0.84-1.43) [i]	1.21 (0.88-1.65)	1.21 (0.88-1.65)[f]

[a]Values in parentheses are 95% CIs. Significant results are marked in bold. HQ ratio, hamstring to quadriceps ratio.

[b]Body mass normalized values.

[c]Side-to-side difference in strength between stronger and weaker leg.

[d]Adjustement factor: previous acute ankle injury.

[e]Adjustement factors: previous acute ankle injury and age.

[f]Adjustement factors: previous acute ankle injury, age and height.

[h]Adjustement factors: previous acute ankle injury, age, height and sport.

[i]Adjustement factors: previous acute ankle injury, age, height, sport and playing at adult level.

FIGURE 1. A, The measurement of maximal one-repetition seated leg press strength. B, the measurement of maximal concentric isokinetic quadriceps and hamstrings strength; C, the measurement of maximal isometric hip abductor strength

FIGURE 2. The flow of players in the study