Physical Exam Risk Factors for Lower Extremity Injury in High School Athletes: A Systematic Review

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Abstract

Objective—A stated goal of the preparticipation physical evaluation (PPE) is to reduce musculoskeletal injury, yet the musculoskeletal portion of the PPE is reportedly of questionable use in assessing lower extremity injury risk in high school-aged athletes. The objectives of this study are: (1) identify clinical assessment tools demonstrated to effectively determine lower extremity injury risk in a prospective setting, and (2) critically assess the methodological quality of prospective lower extremity risk assessment studies that use these tools.

Data Sources—A systematic search was performed in PubMed, CINAHL, UptoDate, Google Scholar, Cochrane Reviews, and SportDiscus. Inclusion criteria were prospective injury risk assessment studies involving athletes primarily ages 13 to 19 that used screening methods that did not require highly specialized equipment. Methodological quality was evaluated with a modified physiotherapy evidence database (PEDro) scale.

Main Results—Nine studies were included. The mean modified PEDro score was 6.0/10 (SD, 1.5). Multidirectional balance (odds ratio [OR], 3.0; CI, 1.5–6.1; $P < 0.05$) and physical maturation status ($P < 0.05$) were predictive of overall injury risk, knee hyperextension was predictive of anterior cruciate ligament injury (OR, 5.0; CI, 1.2–18.4; $P < 0.05$), hip external: internal rotator strength ratio of patellofemoral pain syndrome ($P = 0.02$), and foot posture index of ankle sprain (r = −0.339, $P = 0.008$).

Conclusions—Minimal prospective evidence supports or refutes the use of the functional musculoskeletal exam portion of the current PPE to assess lower extremity injury risk in high

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school athletes. Limited evidence does support inclusion of multidirectional balance assessment and physical maturation status in a musculoskeletal exam as both are generalizable risk factors for lower extremity injury.

Keywords

preparticipation exam; lower extremity injury; high school sports; injury risk assessment

INTRODUCTION

In 1976, the American Medical Association's Committee on Medical Aspects of Sports recognized the importance of the preparticipation physical evaluation (PPE) and recommended completion of a PPE before athletic participation.[1] PPE screening requirements for high school student athletes in the U.S. are typically determined by state legislation, state athletic associations, or individual school districts.[2] The National Federation of State High School Associations considers the PPE a prerequisite to athletics participation, yet its implementation at the secondary school level varies from every year to every 3 years with a majority (36) states requiring a yearly examination.[2] Although the PPE was initially intended to fulfill school-based legal and medical requirements, the primary goal of the current examination is to maximize safe participation in physical activities by adolescents. One of the stated goals according to the PPE fourth edition as it applies to the musculoskeletal exam is to predict individuals at risk for musculoskeletal injury during sports participation,[2] which is a major source of injuries overall in adolescent population.[3–6] Traditionally, the musculoskeletal examination portion of the PPE has been a 2-minute orthopedic screen focused on general range of motion, strength, and joint laxity.[7,8] The current PPE exam has minimal evidence to support or refute its capabilities as an effective predictor of future injuries and offers little direction in the prevention of future musculoskeletal injuries.[8,9] Research is needed to clearly identify useful screening tests for use in the PPE.

A standard PPE (fourth edition 2010)[2] protocol has been recommended by a joint effort of 6 medical associations to be conducted for all youth, regardless of whether individuals are playing sports. With as many as 7,795,658 U.S. adolescents having reportedly participated in sanctioned high school athletics during the 2013 to 2014 school year,[10] duplicate athlete participation most likely lowers this value, recommendations for yearly PPE by qualified members of the medical community create imposing demands on health care practitioners to create time-efficient methods for assessing injury and illness risk. To effectively conduct personalized PPEs, it is recommended that physicians evaluate individuals in a private clinical one-on-one setting,[2,7] yet this is oftentimes not feasible because of the large number of individuals, and mass screenings are commonly conducted for time efficiency and cost-effectiveness. A primary challenge for these types of large-scale screening PPEs is the lack of objective quantifiable information that can be collected in a short period that provides predictive capabilities for identifying individuals at greater risk for musculoskeletal injury.

The purposes of this study are: (1) to identify clinical assessment tools demonstrated to effectively determine risk for acute and chronic lower extremity injuries in a prospective

setting, and (2) to critically assess the methodological quality of prospective lower extremity risk assessment studies that use these tools. We hypothesize that there is no prospective evidence to support routine use of the musculoskeletal (MSK) exam portion of the current PPE and that alternative assessment tools exist that can effectively identify individuals at increased risk for lower extremity injuries. This work addresses a gap in knowledge concerning the efficacy of preparticipation evaluations for the prediction of musculoskeletal injury risk in high school-aged athletics participants as a critical first step for musculoskeletal injury prediction in this age group.

METHODS

Initial Search and Screening

We have adhered to the guidelines outlined in the PRISMA statement for standardized reporting of systematic reviews in the preparation of this article.[11] We initially performed a search of the PubMed database (1975 to November 21, 2014) using the MeSH advanced search tool (Figure). A search that included at least 1 term related to injury (eg, sprain, injury, strain, or tear) and either a term related to evaluation (eg, test, physical, exam, screening, etc.) or disease surveillance (eg, risk factor, prediction, or epidemiologic study) resulted in 183 134 hits; this was further narrowed by requiring an additional MeSH term for anatomic site (eg, ankle, hip, leg, foot, etc.) to 8795 hits, which was then narrowed further to 904 studies by inclusion of the MeSH term "sport." Systematic searches were also performed in CINAHL, UptoDate, Google Scholar, Cochrane Reviews, and SportDiscus and relevant studies previously known by the authors were collected, resulting in 418 additional studies to complete our initial study list for a total of 1322 studies. The titles and abstracts of these 1322 studies were reviewed for our primary inclusion criteria (Table 1); 637 studies from this initial list that were identified as duplicates, review articles, commentary/editorials, or pertaining to an unrelated subject, and an additional 503 studies were excluded that clearly did not meet one or more primary inclusion criteria, resulting in a list of 182 remaining studies. The entire articles of the remaining 182 studies were reviewed for both primary and secondary inclusion criteria (Table 1). For studies in which the secondary criteria were in question, one of the senior authors (JAO) made the final decision for inclusion in the review. Each author made recommendations for studies to include in the systematic review based on the practicality of the clinical screening test and the relevance of the injury risk factor to sports commonly practiced by American high school athletes. A consensus was made from these individual recommendations resulting in the final identification of 9 studies for inclusion in the systematic review (Table 2).

Quality Assessment

The study authors created a modification of the Physiotherapy Evidence Database (PEDro) scale,[21,22] a quality assessment tool based on the Delphi list of criteria for quality assessment of randomized clinical trials for conducting systematic reviews (Table 3).[23] Original items 2 and 3 pertained to subject allocation, which is not relevant to studies of prospective injury risk factors. Our modified item 2 pertained to prospective collection of all baseline study data, and our modified item 3 pertained to performing a power analysis to ensure an adequate sample size, which is inconsistently reported in sports medicine studies.

The language of original item 4 was changed to modified item 5 to reflect an expected difference in some baseline factors in injured versus noninjured study participants. Original items 5 and 6 were combined into modified item 6, as blinding of athletic trainers, athletes, and coaches would be necessary to prevent intentional modification of a perceived injury risk factor (eg, coaches encouraging athletes with low flexibility scores to stretch more often in an effort to reduce injury risk). Finally, original item 9 pertained to correct allocation to treatment or control groups, which was not relevant to prospective injury risk studies; our modified item 9 pertained to accounting for exposure time in matches or practice sessions, thereby allowing for report of injury risk per unit time in addition to absolute risk.

Reliability of Modified PEDro Scale

The final list of 9 studies was circulated among the study authors for blinded quality assessment. Specifically, each blinded reviewer (JRB and AMWC) independently evaluated the 9 studies with the modified PEDro scale and submitted scoring data directly to a designated unblinded study author (JAO). The blinded authors were instructed not to discuss the studies or their scoring results until all blinded reviewers had submitted scores. After the blinded review, the 2 senior authors (TMB and JAO) performed an unblinded review of the 9 studies. Specifically, each discrepantly scored item among the blinded reviewers was reviewed and the unblinded authors assigned a final "gold standard" score after critically appraising the body of the study article. The blinded scores were non-normally distributed ($P = 0.003$ Shapiro–Wilk W), and we therefore used nonparametric reliability tests. Inter-rater reliability of individual blinded reviewers was calculated as Spearman rho, and inter-rater reliability of individual items among blinded reviewers was assessed with Fleiss kappa.

Data Collection and Reporting

The primary purpose, length of time, sample size, age and sex of participants, level of competition, and included sports were reported for all included studies (Table 2). Because the purpose of this review is to assess risk factors for lower extremity injury that are identifiable by examination, we have limited our report of study measures and results to risk factors identifiable in a clinical examination setting with limited equipment (Table 2). Measures of estimated effect size and variability were reported as available. We did not perform any secondary statistical tests on the reported data, and the heterogeneity of reporting methods and experimental design among the included studies was such that we could not perform a meta-analysis or similar method of pooled data analysis. Finally, we documented additional specific strengths and weaknesses of the individual studies that were not directly assessed by the modified PEDro scale but are of potential relevance to interpreting the study findings.

RESULTS

Study Characteristics

After our screening process was completed, 9 prospective cohort studies including high school age athletes were identified (Table 2). One study was specific to soccer players,[13] 3 studies were specific to track and field or running,[12,14,15] 2 were specific to basketball,[18,20] 1 was specific to American football,[19] and 2 included multiple sports.[16,17] Three were

limited to male athletes,[13,15,19] 1 was limited to female athletes,[17] and 5 included both sexes. Sample size ranged from 42[20] to 1558[17] athletes, and athletes were followed 2 to 4 sports seasons in 4 studies[15–17,19] and a single season for the remaining 5 studies.[12–14,18,20] The overall injury prevalence in the reported studies ranged from 1.2% for anterior cruciate ligament (ACL) tears among female high school athletes[17] to 43% for ankle injuries among soccer players.[20] The most common definition of injury included missed practice or game time (6 of 9 studies).[13,15,16,18–20] Injury severity was reported based on time lost in 2 studies[15,20] and by a clinical scoring system in 1 study.[16] Five studies required clinical evaluation by an athletic trainer, physical therapist, or physician,[12,14–16,20] 1 study allowed injury report by the coach or athletic trainer,[18] and 1 study required diagnostic imaging or arthroscopic visualization.[17]

Methodological Quality and Modified PEDro Score Reliability

The mean modified PEDro score for the included studies was 6.0 ± 1.5 (Table 3) for the gold standard review, which was not significantly different from the distribution of unblinded scores (median, 8; interquartile range, 6–8; $P = 0.95$ Wilcoxon rank sum). None of the studies fulfilled all criteria in the modified PEDro scale (modified PEDro score of 10). However, 2 of 9 studies attained a high score of 8 of 10,[17,18] and 2 of 9 studies attained a low score of 4 of 10.[12,20] Of the individual factors on the modified PEDro scale, item 3 had the lowest percentage of studies that met the specified criteria (1/9 or 11%),[16] which was use of a power analysis to determine appropriate sample size. There was moderate correlation among blinded reviewers for both the total study score (Spearman rho = 0.63) and item-specific responses (Fleiss kappa = 0.46).

Identified Clinical Exam Injury Risk Factors

No prospective studies that met our inclusion criteria were identified that included evaluation of all or part of the functional examination recommended in the PPE fourth ed. (the duck walk or single-leg hop).[2] Our review identified several clinical examination modalities that have at least preliminary evidence to suggest efficacy in stratifying future lower extremity injury risk. Identified risk factors fell into 7 basic categories: balance,[18,20] anatomy,[12,13] strength,[14] physical maturation status,[15] weight,[16] and ligamentous laxity.[17] Modalities such as the Star Excursion Balance Test (SEBT) and assessment of physical maturation are broadly associated with increased injury risk,[15,18] whereas most assessments included in this review are specific to individual injuries.[12–20] Our assessments of these risk factors are as follows:

Physical Maturation Status

Delayed physical maturation status is associated with increased acute lower extremity injury in school-aged athletes.[24–26] Only 1 study examined the relationship between physical maturation status and overuse lower extremity injury but found that boys under the age of 14 were more likely to get injured.[25] This study evaluated physical maturation by comparing participants' skeletal maturity assessed through radiographs with their chronological ages.[25] An early maturer was defined as an individual with a skeletal age 1 year above their chronological age and a late maturer was defined as an individual with a skeletal age 1 year below their chronological age.[25] However, determination of maturation status by comparing

skeletal maturity and chronological age is problematic for general screening because of the required radiographs. Fourchet et al[15] presents an interesting association between age of peak height velocity and overall injury risk in a study population that includes track and field athletes that participate in a variety of events. Age of peak height velocity as a surrogate measure of maturation status can be calculated based on serial height measurements and has the potential for incorporation into a clinical injury risk assessment. One requirement for this type of assessment is either continual yearly access to the same primary care provider or an electronic medical record system that is accessible to allow parents and children to track and maintain their yearly physical maturation information.

Balance

Based on our review, poor balance seems to be a likely risk factor for ankle sprain in high school-aged athletes in sports with a high incidence of ankle injuries, as 2 included studies had positive findings[18,20] and 1 had negative findings.[16] However, the methodology of each balance testing procedure varied significantly, and differences in study populations limit direct comparison of test results. McHugh et al[16] examined frontal plane excursion (uniplanar balance) on a tilt board as measure of percent time out of balance, Wang et al[20] used degree of postural sway (multidirectional balance) on a force plate, and Plisky et al[18] used a clinical exam (SEBT) of reach distance in multiple planes before losing balance (multidirectional balance). The SEBT relies on minimal equipment and seems to be conducive to a clinical setting. Although Plisky et al reported increased overall lower extremity (LE) injury risk based on SEBT results, injury data regarding anatomic distribution (knee vs ankle vs hip) was not reported and limited the specificity of his results.

Anatomic Factors

Four studies in this review examined anatomic injury risk factors, particularly leg length asymmetry and foot morphology. Leg length asymmetry is proposed to result in asymmetrical gait and postural changes with compensatory imbalances in muscle strength and flexibility,[30,31] with some promise as a predictive tool for stress fractures in select populations such as track and field athletes.[32] Limb length discrepancy is measured most accurately with radiographic methods,[30] which may be inappropriate for general screening in a pediatric population. Finnoff et al[14] reported negative findings regarding length discrepancy as a risk factor for patellofemoral pain syndrome (PFPS); however, this measure has not been previously associated with PFPS and seemed to be a secondary aspect of their overall study design. Both excessive foot pronation and supination have also been proposed to increase lower extremity injury risk[33–35]; correspondingly, a pronatory foot type as measured through navicular drop was associated with increased risk of medial tibial stress syndrome (MTSS) by Bennet et al[12] and Cain et al[13] reported that supination as measured by the Foot Posture Index was associated with ankle overuse injury. However, the small sample size, single sport design, narrow injury definition, and varied methods of determining foot type in these studies again limit the applicability of this screening modality to a general athletic population.

Strength

Based on our review, maximum isometric strength was not a risk factor for injury but strength ratios between agonistic and antagonistic muscle groups were predictive of injury. Specifically, Wang et al and McHugh et al found no association between ankle injury and leg strength.[16,20] In a more generalized model, Turbeville et al[19] used hand grip strength as a surrogate measure of overall strength and also found no association with injury of any type among football players. However, when examining strength imbalance, Finnoff et al[14] noted a protective effect from a low external rotation (ER): internal rotation (IR) hip strength ratio and an increased risk of PFPS at higher ratios in runners. The narrow scope of this study, both in athlete population and injury of interest, limits the applicability of their findings, and future research of strength imbalance as an injury assessment tool in a multisports setting with a broader definition of injury may be warranted.

Ligamentous Laxity

Myer et al[17] was the only study to assess joint laxity in our review, which is a known risk factor for ACL injury.[36,37] The authors conclude that screening of ligamentous laxity may effectively identify high school female athletes at increased risk of ACL injury who participate in soccer and basketball.[17]

DISCUSSION

Injury risk assessment in high school athletes has been a long-standing goal of sports medicine practitioners. One of the challenges of developing an assessment tool to determine relative injury risk is the large range of activities performed by athletes even within a given sport and the wide variation in physical maturity within this age group. Accordingly, multiple assessment strategies have been proposed with varying degrees of specificity to a given population, yielding equally varied results. After extensive review of the literature, we found no evidence to support or refute use of the PPE fourth ed. format for prospective musculoskeletal injury risk assessment in high school-aged athletes. There seems to be a moderate level of evidence supporting several physical examination findings, including ligamentous laxity,[17] strength imbalance,[14] excessive foot pronation or supination,[12,13] physical maturation status,[15] and multidirectional balance[18,20] in high school-aged athletes as risk factors for future injury, although their utility is often limited to a narrow spectrum of sports or to prediction of specific injuries.

One of the stated goals of the PPE is to identify those at risk for injury. Although self-report of previous injuries[38] or the presence of persistent functional deficits[28,29,39] are risk factors for future injury, the results of this review demonstrate that there is no objective evidence that the recommended components of the MSK examination portion of the PPE provide relevant prospective risk assessment data in high school-aged athletes. In addition to the general MSK examination, a functional assessment of 2 movements, the duck walk and single-leg hop, is recommended.[2] Based on our systematic search of the literature, there are no reported prospective injury risk assessment studies in high school-aged athletes that include evaluation of these movements. However, evidence-based assessments were identified that could replace these qualitative assessments in a clinical setting. In particular,

both the SEBT and age of peak height velocity as a measure of physical maturation status are both easily reproducible and associated with overall lower extremity injury risk.[15,18] These types of assessments can easily be performed in a primary care provider's standard office setting and requires minimal training for reliable data collection. One limitation is nonstandard reporting of data (no odds ratio or correlation coefficients reported) and an overly broad definition of injury severely limits the interpretability of peak height velocity for lower extremity injury risk assessment. Future studies that clearly report relative risk and injury data are needed to determine the reliability of age of peak height velocity as an injury risk factor. However, this information does highlight the use of serial type measurements and the importance of primary care provider yearly access to help make better informed decisions using longitudinal tracking on an individual basis. Future studies are indicated to develop a more comprehensive evidence-based examination, but it is clear that sufficient evidence exists to at least moderately improve on the currently recommended assessment process.

Quantitative analysis of knee hyperextension as a surrogate for joint laxity may provide some insight into lower extremity injury risk (ie, ACL injury), which can be readily accomplished in a clinical examination setting, it is likely inappropriate for general screening because of the low overall incidence of ACL injury, but it may be more appropriate as a future component of the PPE for female athletes in high ACL injury risk sports (eg, soccer and basketball). Sport specific PPE testing may not be time efficient, but discussions between primary care providers and their patients will help them discern which specialized tests may be warranted based on an individual's values and physical activity goals. One generalized risk assessment tool that has had promising results in 2 recent prospective studies of collegiate and professional level athletes is the Functional Movement Screen (FMS).[40,41] This screening tool was developed under the premise that functional testing of movements that simultaneously integrate aspects of neuromuscular coordination, balance, strength, and flexibility can effectively determine injury risk because of the likely multifactorial etiology of acute sports injuries.[27,42–45] The FMS requires qualitative evaluation of the controlled execution of several movements of varying complexity (deep squat, shoulder mobility, hurdle step, lunge, straight leg raise, push-up, and rotary stability).[44,46] With high inter-rater reliability (0.7–0.9)[47,48] and minimal equipment needed to perform this screening tool, additional study of the FMS as a generalized lower extremity risk assessment tool in high school athletes is merited.

In an effort to facilitate improved design of future sports injury risk assessment studies and evaluation of methodological quality of previous injury risk studies, the authors have presented our initial experiences with the modified PEDro scale. Our results indicate that this scale provides a reasonable general assessment of study quality. However, it is not meant to substitute well-defined inclusion criteria for a systematic review. Several components of prospective study design were emphasized in our modified scale that are inconsistently present in this field of research, namely participant blinding, sample size estimation, and report of sports exposure hours. We believe that the importance of blinding study participants from the results of risk assessment tools is under-appreciated. Athletes, coaches, and clinicians alike are motivated to keep participants healthy, and blinding is necessary to minimize the likelihood of active attempts to modify the perceived risk factor (even if it is a

spurious assumption) in an attempt to prevent injury. In addition, sports exposure is an essential component of injury risk, and it has been well-established that playing time during sporting events confers a higher risk of injury than training hours.[49–53] Even if an injury risk assessment study had adequate sample size, it would be underpowered if the enrolled athletes did not have sufficient sports exposure to sustain the anticipated number of injuries.

Limitations of this review are related to the heterogeneity of the selected studies in addition to assumptions of overall study quality made by our modified PEDro score. Our modified scale and the original PEDro are designed to determine the quality of the study design as it is reported in the article, which does not take into account possible discordance in study report and actual study design.[22] In addition, because our review centers on risk assessment in a relatively broad athlete population, the studies that met our inclusion criteria had respectively varied study populations, precluding direct comparison between risk assessment tools. The lack of clarity between risk factors for acute and chronic injuries created an additional limitation.

It is possible that some risk factors are different for acute and chronic injuries and because the research reviewed did not consistently distinguish between acute and chronic injuries the results of this review would not clearly identify risk factors that may be indicative of certain types of injury. Finally, because most of sport injury risk assessment studies that met our criteria focused on a given sport or a specific injury, there is a paucity of studies that broadly evaluate a given risk assessment tool for general screening in a setting such as the sports preparticipation evaluation (PPE). There were several common methodological limitations in the identified studies that undoubtedly introduced a bias toward negative findings. There was typically a lack of reported power analyses to determine adequate sample size, despite an abundance of epidemiologic reports from which to draw incidence and prevalence data for acute high school sports injuries when estimating sample size for study design.[3–5,54–69] Only one of the studies in this review had a reported method of sample size estimation,[16] and athlete exposure hours was only reported in 2/9 studies.[15,17] Additionally, injuries were reported in a nonstandard manner ranging from self-report of symptoms to missed practice time to diagnosis by a sports medicine provider. Therefore, to improve efforts at identifying reliable sports injury risk assessment tools, it is imperative that future risk assessment studies demonstrate adequate sample size, report injury risk in a standard manner, record sport exposure time, and use a reliable working injury definition.

In conclusion, no prospective studies were identified in this review that support or refute use of the functional MK examination portion of the currently recommended sports preparticipation evaluation to assess injury risk in high school-aged athletes. There is some prospective evidence to support generalized use of the SEBT and assessment of physical maturation status by age of peak height velocity to prospectively determine lower extremity injury risk. Several injury-specific risk assessment tools, such as the FMS, hip muscle strength ratios, foot pronation measurements, ankle dorsiflexion range of motion, and dynamic functional hop tests may yield improved benefit for prospectively evaluating lower extremity injury risk for high school athletes entering specific sports or positions of increased lower extremity risk exposure.

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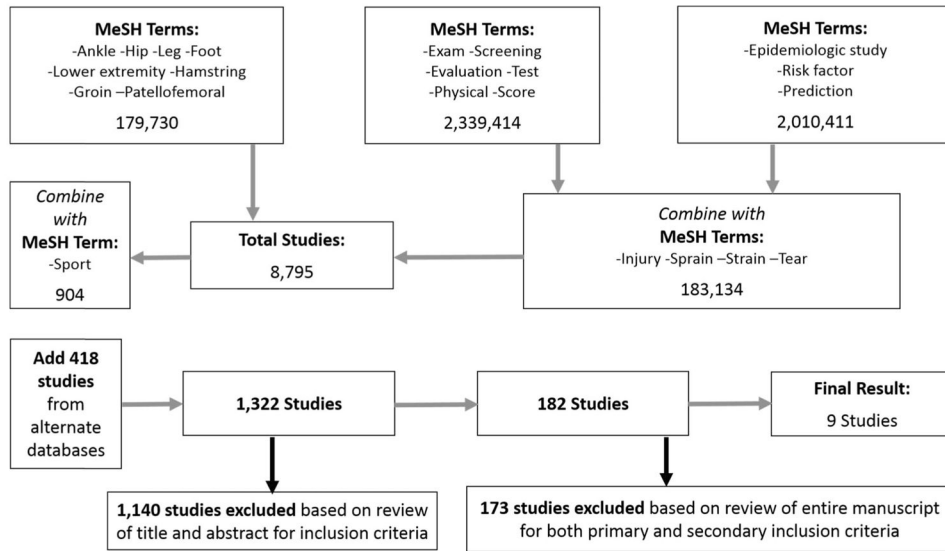
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MeSH Terms: -Ankle -Hip -Leg -Foot -Lower extremity -Hamstring -Groin –Patellofemoral 179,730	**MeSH Terms:** -Exam -Screening -Evaluation -Test -Physical -Score 2,339,414	**MeSH Terms:** -Epidemiologic study -Risk factor -Prediction 2,010,411

Combine with **MeSH Term:** -Sport 904 ← **Total Studies:** 8,795 ← *Combine with* **MeSH Terms:** -Injury -Sprain –Strain –Tear 183,134

Add 418 studies from alternate databases → **1,322 Studies** → **182 Studies** → **Final Result:** 9 Studies

1,140 studies excluded based on review of title and abstract for inclusion criteria

173 studies excluded based on review of entire manuscript for both primary and secondary inclusion criteria

FIGURE.

Initial PubMed MeSH search and subsequent screening process.

TABLE 1

Study Inclusion Criteria

Inclusion	Exclusion
Primary criteria	
Studies investigating lower extremity injury prediction or risk factors	Studies not reporting original research including review articles, expert opinion, or current concepts articles
Study population consists primarily of physically active individuals (athletes or military) of any level of experience (eg, recreational, college, professional, etc.)	Posters or abstracts at annual meetings or masters theses without subsequent peer-reviewed publication of a article
At least one of the injury risk factors being studied is a physical exam test	Studies investigating risk factors identifiable only by imaging or laboratory testing
Study is peer-reviewed	Animal studies
Study reports original data	Studies investigating osteoarthritis
Level 1–4 evidence according to CEBM criteria	Studies investigating risk factors based on patient history alone (eg, patient demographics, activity level, participating sport, or injury history)
Study is reported in English	
Secondary criteria	
Study population consists primarily of adolescent to young-adult (ages 13–19 yrs) athletes	Length of physical exam test exceeding 15 minutes for single-patient exam format or 1 h for multistation format
Clinical screening test be performed in a single-patient exam format or a multistation format	Studies drawing conclusions regarding injury risk or injury prediction based on historical data
Prospective study design	

TABLE 2

Nine Studies Identified for Inclusion in Systematic Review

Author	Purpose	Methodology and Participants	Measures	Injury Incidence and Prevalence	Identified Risk Factors	PEDro Score	Limitations	Strengths
Bennett et al[12]	Evaluate foot type as predictor of medial tibial stress syndrome	High school runners, single season n = 125	Navicular drop, gastroc length, rearfoot angle, tibiofibular varum	15/125 runners (12% total; 2/57 or 4% men, 13/68 or 19%) or women had MTSS symptoms. Incidence not reported.	Sex and navicular drop associated with MTSS ($r^2 = 0.18$ navicular drop; $r^2 = 0.24$ sex, $P < 0.05$). OR not reported	5	Assessment of MTSS did not explicitly rule out stress fracture with bone scan/radiograph, navicular drop was measured postinjury	Easily obtainable measure, highly specific clinical definition of MTSS
Cain et al[13]	Evaluate foot pronation/supination as risk factor for foot/ankle overuse injury	High school-aged male indoor soccer players, single season n = 76	Foot Posture Index, coach-rated ability	32% of players sustained at least 1 ankle/foot injury during the season. Incidence not reported	Supination and under pronation (FPI score less than 2) associated with foot/ankle overuse injury (sensitivity 89% specificity 50%)	8	Male participants only, foot posture index scoring system requiring significant training of novice evaluators (two 2-h sessions)	Playing h factored into analysis, injury defined by self-report of pain resulting in missed h
Finnoff et al[14]	Evaluate hip strength as a risk factor for PFPS in high school runners	High school runners, age 14–18 yrs, single season (n = 98)	Weight, leg lengths, isometric hip strength (external rotation, internal rotation, abduction, adduction, flexion, extension)	5/98 subjects experiences PFPS symptoms. 2/53 or 3.7% men, 3/44 or 6.8% women. Incidence not reported	Lower hip ER:IR strength ratio increased risk of PFPS ($P = 0.08$); higher ER:IR ratio was protective (OR < 0.01; CI < 0.01–0.44; P = −0.02). Higher abd strength (OR, 5.4; CI, 1.5–29.5; $P < 0.01$) and abd: add ratio (OR, 14.14; CI, 0.90–220; $P = 0.05$) increased risk	5	Low recruitment rates, reenrollment of 4/98 subjects across multiple seasons, unable to report reliability data for strength testing	Easily testable in clinic setting, also reported effect of agonist-antagonist strength imbalance in addition to individual muscle groups
McHugh et al[16]	Evaluate balance and hip strength as predictors of ankle injury	High school-aged male and female football, basketball, gymnastics, and American football players, 2 seasons, (n = 169)	Hip flexion, abduction, adduction, strength through hand-held dynamometer, single-limb balance on tilt board, body mass index, ligamentous laxity	27 lateral ankle sprains recorded. Incidence 1.47/1000 exposures. Prevalence of injured athletes not reported	Higher body mass index in male athletes and history of previous ankle strain were significant predictors of injury; balance and strength were not ($P > 0.05$)	8	Injury prevalence not reported in detail. Nonstandard report of incidence. Did not discriminate between game or practice time	Large sample size, 2-yr follow-up, men and women included in model, previous injury included in model, power analysis conducted, training h considered in model

Author	Purpose	Methodology and Participants	Measures	Injury Incidence and Prevalence	Identified Risk Factors	PEDro Score	Limitations	Strengths
Myer et al[17]	Evaluate joint laxity as ACL injury risk factor in female athletes	Female high school–aged soccer and basketball players, 4 seasons, (n = 95 nested case–control from total n = 1558)	Generalized joint laxity tests, AP tibiofemoral translation (CompuKT knee arthrometer) in bilateral knees	19/1558 subjects sustained ACL tears (1.2%). Incidence not reported	Side to side differences in knee laxity associated with increased ACL injury risk (OR, 4.0 per 1.3 mm difference; CI, 1.7–9.7). Positive knee hyperextension increased injury risk (OR, 5.0; CI, 1.2–18.4)	8	Model restricted to ACL injury only, requires specialized equipment, training h not included in model	Nested case–control design with internally validated prediction model, large sample size, broad population of interest
Plisky et al[18]	Evaluate balance as a risk factor for lower extremity injury in basketball players	Male and female high school basketball players, single season (n = 235)	SEBT	54/235 (23%) of athletes sustain a LE injury. Incidence not reported	R/L reach distance disparity >4 cm increased injury risk OR, 2.7; CI, 1.4–5.3 all, 3.0 (1.1–7.7 men). Normalized composite reach distance less than 94% increased LE injury risk (OR, 3.0; CI, 1.5–6.1 all; OR, 6.5; CI, 2.4–17.5 women)	7	19% dropout rate, multiple trials required for accurate SEBT assessment, training h not included in model	Previous injury accounted for in model, large sample size, men and women
Turbeville et al[19]	Evaluate risk factors for injury in high school American football players	High school–aged male American football players (13–19 yrs), 2 seasons (n = 717)	Report of preseason conditioning, body mass index, grip strength, playing experience	132 injuries reported among 100/717 (13.9%) players over 2 seasons. 62% were LE injuries; 38% were UE injuries. Incidence not reported	Physical characteristic were not associated with injury risk. Players with previous injuries or more playing experience (OR, 1.34) at increased LE injury risk	6	Study-designed for overall injury risk, injury rates underreported relative to historical data, individual training h not included in model	Easily obtainable measures, data applicable to specific positions played, preseason conditioning and use of special equipment (eg, brace) recorded
Wang et al[20]	Evaluate ankle injury risk factors in high school basketball players	High school male and female basketball players, single season, (n = 42)	Isokinetic ankle strength (Cybex 6000, Biodex dynamometer), ankle ROM, ankle endurance, postural sway (forceplate)	18/42 (43%) players sustained ankle injuries; incidence not reported	Postural sway was only variable associated with injury (OR, 1.2; CI, 1.09–1.36; $P < 0.01$)	6	25% dropout rate, specialized equipment required, small sample size	Training h included in model, strict inclusion criteria with control for shoe type, bracing, training surface

TABLE 3

Original and Modified PEDro Scales

Assessment	Revised Category	Original Category
External validity/applicability	1. Eligibility criteria were specified	1. Eligibility criteria were specified
Internal validity	2. All measures were obtained before sports season onset (prospective design)	2. Subjects were randomly allocated to groups
	3. A power analysis was performed to determine sample size	3. Allocation was concealed
	4. Reliability data was available for all applicable measures	4. The groups were similar at baseline regarding the most important prognostic indicators
	5. Other than the measures of interest, the groups were similar at baseline regarding the most important prognostic indicators	5. There was blinding of all subjects
	6. There was blinding of athletes, trainers, and sports coaches to baseline measures of interest	6. There was blinding of all therapists who administered the therapy
	7. There was blinding of all assessors of injury to baseline measures of interest	7. There was blinding of all assessors who measured at least 1 key outcome
	8. Measures of at least 1 key outcome were obtained from more than 85% of the subjects initially recruited	8. Measures of at least 1 key outcome were obtained from more than 85% of the subjects initially allocated to groups
	9. Before injury, both groups had nonsignificant differences in sport exposure (both practice time and match time), or this was corrected for in the statistical analysis if found to be unequal	9. All subjects for whom outcome measures were available received the treatment or control condition as allocated
Interpretability	10. The results of between-group statistical comparisons are reported for at least 1 key outcome	10. The results of between-group statistical comparisons are reported for at least 1 key outcome
	11. The study provides both point measures and measures of variability for at least 1 key outcome	11. The study provides both point measures and measures of variability for at least 1 key outcome
Scoring	Assign 1 point for each item in criteria 2–11 that is met. The first criterion is not included in the total. All points are summed to yield a total score of up to 10 points	