





BMJ Open Practicability of lower extremity functional performance tests and their measurement properties in elite athletes: protocol for a systematic review

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ABSTRACT

Introduction Lower extremity injury (LEI) is highly prevalent and its occurrence increases the risk of future injury in athletic populations. Identifying athletes at risk of injury is the key to target injury-prevention programmes. Functional performance tests (FPT) assess an athlete's ability to produce and accept forces during movement tasks reflective of those experienced in sport, and are used to identify deficits in physical qualities or neuromuscular control. This review aims to identify FPT which have potential to predict LEI and assess their measurement properties associated with reliability, validity, responsiveness and practicability (interpretability and feasibility).

Methods/analysis This protocol will be reported using the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol and the COnsensus-based Standards for the selection of health Measurement INstruments Methodology. The search strategy has two stages: stage 1 will identify lower limb FPT used in athletic populations; and stage 2 will assess the measurement properties of the identified FPT. A sensitive search strategy will use MEDLINE, EMBASE, CINHAL and SPORTdiscus databases; from inception to June 2020. Hand searching reference lists, key journals and grey literature will be completed. One reviewer will complete search 1 and data extraction. Two reviewers will complete the search, data extraction and risk-of-bias assessment for search 2. Evidence will be pooled or summarised by individual measurement property by each individual study and grouped by FPT. Meta-analysis using a random effects model with subgroup analysis will be performed where possible. Pooled or summarised results for each FPT in relation to each measurement property will be rated against the criteria for good measurement properties. Two reviewers will assess the overall body of evidence per measurement property per FPT using the modified Grading of Recommendations, Assessment, Development and Evaluation guidelines. This review will enable clinicians to make an informed choice when selecting FPT.

Ethics and dissemination No ethical approval is required for this review and the results will be disseminated through peer-reviewed publications and submitted for conference presentation.

PROSPERO registration number CRD42020188932.

Strengths and limitations of this study

- This review will, for the first time, identify, assess quality, and report the available evidence for functional performance tests (FPT) that have the potential to predict a lower extremity injury (LEI) in elite athletic populations.
- A two-staged process will enable a sensitive search to first identify FPTs and second to evaluate their measurement properties.
- The COnsensus-based Standards for the selection of health Measurement INstruments risk-of-bias tool and modified Grading of Recommendations, Assessment, Development and Evaluation approach will be used.
- Findings will enable practitioners to select tests which have the ability to predict LEI in an elite athletic population.

INTRODUCTION

Lower extremity injury (LEI) represents a significant burden in athletic populations across sports.

Reviews of injury surveillance data within the National Collegiate Athletic Association consistently demonstrate LEI to account for more than 50% of total injuries.^{1–5} The trend of high rates of LEI is also seen in other sporting cohorts. LEI accounted for 57% of injuries reported in the Union of European Football Associations (UEFA) Elite Club Injury study⁶ with thigh (34%), knee (12%) and hip/groin (11%) among the most common during 2018/2019 men's season. Within women's football, LEIs are the most common injuries and often more severe.^{2,5,7–10} Female players experience greater time loss and longer return to play times, for thigh and calf muscle strains and anterior cruciate ligament (ACL) injuries compared with male players.¹⁰ Female athletes have significant differences in relation to their anatomy,

hormonal profile and neuromuscular qualities compared with male athletes, which have been linked to high injury risk movement patterns.^{11–18} This may explain why across sports, female athletes present with more severe LEI to the knee and ankle and with greater time loss from training and competition.^{2–5 9–13 19} Previous LEI has been identified as a risk for future injury which when it occurs, may be more severe, may require surgical intervention and a prolonged rehabilitation period.^{20–23} Prevention of a primary LEI may lead to a healthier athletic population who are able to complete greater volumes and intensity of training, which have been shown to decrease future injury rate and improve performance.^{24–27}

Evaluation of physical status is assessed on commencement and continuously throughout athletic careers. Data are used to assess physical qualities, inform training prescription and exposure to training load.^{26 28} It also informs interventions and rehabilitation as part of return to training and performance.^{29–35} Traditional clinical assessment techniques such as joint range of motion, ligament laxity and manual muscle testing have limited value to determine an athlete's injury risk.^{16 32 36 37} Laboratory testing is considered the 'gold standard' when analysing movement patterns and forces that are potentially injurious, but methods are often expensive and require laboratory time.^{38 39} Field-based testing also permits larger numbers of athletes to be regularly profiled without the need for specialist skills or expensive and time intensive methods such as three-dimensional motion capture and kinematic analysis.^{39–44}

Functional performance tests (FPT)^{37 45} are quantitative measures used to define function and/or outcome. FPT include assessment of an individuals' ability to coordinate their neuromuscular system to produce, accept and adapt to multiplanar forces occurring in movement patterns which mimic or are similar to those required for sporting performance. There are a variety of terms to describe this form of assessment including field expedient tests,⁴⁶ functional outcome measures and physical performance tests.^{47 48} FPT such as Functional Hop Test,⁴⁹ Landing Error Scoring System^{50 51} and Star Excursion Balance Test^{52 53} are commonly used to assess a specific condition (eg, chronic ankle instability^{52 54}, ACL injury^{39 55–59}) or specific cohorts of athletes (eg, female basketball players, prepubescent athletes).^{45 55–64}

Poor performance in FPT has been linked to increased risk of injury due to a deficit in physical qualities or neuromuscular control. The Y-balance test is associated with increased injury risk when there is a difference of >4 cm between limbs.^{48 52} Combining FPT into a testing battery to assess a variety of physical and movement qualities has shown capacity to identify athletes at risk of LEI.^{45 65 66} Brumitt *et al.*⁶⁵ tested three FPT in preseason with a cohort of 106 division III female athletes across 8 sports. They were able to identify risk profiles based on two or more suboptimal scores which were associated with an increased risk of LEI and time loss from training/competition. Categorising athletes into high and low risk

groups enables targeted injury-prevention interventions which in turn may be a more cost-effective use of health-care resources through decreasing injury rates.^{45 65 66}

Knowledge of FPT measurement properties is essential to evaluate the quality of the results produced by the FPT and if it is appropriate for its intended use. This enables understanding of the influence of individual FPT and how they contribute to a composite score such as the Functional Movement Score.^{45 65–69} The COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) taxonomy of measurement properties has three domains which are reliability, validity and responsiveness.⁷⁰ Further subgroupings of interpretability and feasibility are also described within the COSMIN systematic review methodology.⁷¹ Interpretability and feasibility can be combined to form the domain practicability which is important when considering which FPT to use in the field.³⁹ COSMIN methodology applies a robust and rigorous assessment of measurement properties and a systematic review using this approach is required to inform practitioners and researchers which FPT can be used with athletic populations to identify those at risk of LEI.

AIM

To identify, evaluate and report FPT that identify athletes at risk of, or who sustain an LEI, and report their measurement properties.

Objectives

1. To identify FPT that have been used in elite athletic population to identify individuals at risk of sustaining an LEI.
2. To evaluate and report for each FPT: reliability (internal consistency, test–retest, inter-rater and intrarater), validity (content, structural or criterion), measurement error, responsiveness and practicability (interpretability/feasibility)
3. To synthesise the available evidence, assess and report the quality of FPT measurement properties using the modified Grading of Recommendations, Assessment, Development and Evaluation (GRADE) criteria.

METHODS

Design, protocol and registration

This systematic review protocol has been designed using the Preferred Reporting Items for Systematic review and Meta-Analysis Protocol (PRISMA-P)⁷² and COSMIN methodology for a systematic review of outcome measures.⁷¹ The protocol is registered on PROSPERO and is reported in line with PRISMA-P. The systematic review will be conducted in two stages with two searches. Search 1 will identify the FPT used to predict LEI (objective 1), and search 2 will use the identified FPT as search terms to identify studies which evaluate measurement properties of the measures (objective 2). Modified GRADE criteria

Table 1 Inclusion/exclusion criteria for search 1: Identification of FPT

Components	Inclusion criteria	Exclusion criteria
Construct	<ul style="list-style-type: none"> ▶ The FPT have predicted musculoskeletal injury to lower extremity—acute, chronic or recurrent ▶ The FPT have ability to differentiated between injured and non-injured athletes 	<ul style="list-style-type: none"> ▶ Prediction of secondary injury
Population	<ul style="list-style-type: none"> ▶ Athletes (elite, pre-elite, collegiate) ▶ >16 years old 	<ul style="list-style-type: none"> ▶ Non-athletic populations in rehabilitation settings ▶ Recreational level athletes
Types of instrument	<ul style="list-style-type: none"> ▶ FPT of the lower extremity (hip terminal phalanges of foot) ▶ FPT which can feasibly be completed in the field of play requiring minimal equipment 	
Study design	<ul style="list-style-type: none"> ▶ Randomised control trial ▶ Cohort studies ▶ Observational studies ▶ Prospective study design 	<ul style="list-style-type: none"> ▶ Case studies
Limits	<ul style="list-style-type: none"> ▶ Studies reported in English 	

FPT, functional performance tests.

will then be applied to the evidence synthesised from search 2 (objective 3).

Eligibility criteria

Search 1: identification of FPT

Search 1 will identify relevant FPT which are predictive of LEI in an athletic population. [Table 1](#) outlines the eligibility criteria for article selection. These criteria were informed by the key elements outline in the COSMIN methodology for systematic reviews.⁷¹

Search 2: measurement properties of FPT

Following search 1, the identified FPT will be searched for within the literature using search terms in relation to FPT naming conventions, lower limb injury and measurement properties. Measurement properties of the FPT that have demonstrated ability to predict injury are the outcomes of interest as outlined in [table 2](#). These criteria were informed by the key elements outline in the COSMIN methodology for systematic reviews.^{71 72}

Patient and public involvement

The study was developed as a result of conversations with athletes and coaching staff about the value of the information generated through screening for injury risk. The athlete's perspective is that they want to know how they have performed in relation to their teammates, peers and competitors. While coaching staff wish to know that the time invested in screening is providing information that is useful and informs training and performance. These two different perspectives have informed the question and design of the review in an attempt to answer this. No athlete data will be required during data collection or analysis but the results of this review will be made available for athletes, coaches and support staff in sports where LEIs are a significant burden.

Information sources

The following databases will be used in the search: MEDLINE, EMBASE, Cumulative Index to Nursing and Allied Health Literature, and SPORTDiscus. These databases will be used for both stages of searches. The databases outlined in the search strategy will be used in both searches 1 and 2. Hand searching will include the reference lists from articles identified in both searches. Hand searching for the timespan of 1991–2020 of the following journals will be completed: *British Journal of Sports and exercise Medicine*, *Physical Therapy in Sport*, *Journal of Strength and Conditioning research*, *Journal of Orthopaedic and Sports Physical therapy* and *Journal of Athletic Training*. Grey Literature will be searched using the British national bibliography for report literature, electronic thesis online service for dissertations and abstracts and Open Grey.

Search strategy

In order to identify relevant studies and to achieve a comprehensive systematic review, a reproducible search strategy has been devised and completed by one reviewer (RC) for search 1 and two reviewers (RC and LH) for search 2. The search strategy will use MEDLINE terms and keywords and the search strategy is detailed in [box 1](#). Search terms will be amended for individual differences of each database as required.⁷¹ For search 2, a search filter for measurement properties will be applied in appropriate databases to improve the accuracy.^{71 73} For both searches there will be no limitations to date of publication; however, only human studies and those reported in English, and where there is access to full-text articles, will be included and reviewed.

Table 2 Inclusion/Exclusion criteria for search 2 – measurement properties of identified FPT

Components	Inclusion criteria	Exclusion criteria
Construct	Reports measurement properties related to <ul style="list-style-type: none"> ▶ Reliability ▶ Validity ▶ Responsiveness ▶ Practicability (Interpretability/feasibility) 	<ul style="list-style-type: none"> ▶ Solely describes the test
Population	<ul style="list-style-type: none"> ▶ Athletes (elite, pre-elite, collegiate) ▶ >16 years old 	<ul style="list-style-type: none"> ▶ Non-athletic populations in rehabilitation settings ▶ Recreational level athletes
Types of instrument	<ul style="list-style-type: none"> ▶ FPT of the lower extremity (hip terminal phalanges of foot) ▶ FPT which can feasibly be completed in the field of play requiring minimal equipment 	
Study design	<ul style="list-style-type: none"> ▶ Randomised control trial ▶ Cohort studies ▶ Observational studies ▶ Prospective study design 	<ul style="list-style-type: none"> ▶ Case studies
Limits	<ul style="list-style-type: none"> ▶ Studies reported in English 	

FPT, functional performance tests.

Study records

Data management

Results from searches will be imported into End Note V.X8 (Clarivate Analytics) reference management software.

Selection process

A PRISMA flow chart (figure 1) presents the number of papers identified by both searches and those which were included in the final review with reasons for exclusion detailed.

Titles and abstracts will be screened by two reviewers (RC and LH) independently for inclusion. Where a study achieves ‘undecided’ at this first review a full text will be requested in order for a decision to be made. Full text of

Box 1 Search strategy for MEDLINE

Search 1

1. lower extremity.mp.
2. exp lower extremity/
3. exp lower limb/
4. hip.mp
5. knee.mp
6. ankle.mp
7. foot.mp
8. exp anterior cruciate ligament
9. exp acl
10. exp lateral ankle ligament
11. exp chronic ankle
12. injury.mp.
13. exp injury/
14. ligament injuries.mp
15. joint instability.mp
16. strain/sprain.mp
17. exp strain/sprain
18. Athlete.mpathlete.mp.
19. exp Athleteathlete/
20. screening.mp.
21. exp screening/
22. preparticipation screening.mp
23. physical performance test.mp.
24. functional performance test.mp.
25. functional outcome measure.mp
26. field expedient test.mp
27. movement screen.mp.
28. functional movement score.mp
29. exp hop test/
30. exp fitness test/
31. exp single leg squat
32. exp vertical jump
33. exp star excursion balance test
34. exp Y balance test
35. exp tuck jump
36. exp landing error scoring system
37. 1–7/OR
38. 8–17/OR
39. 18 OR 19
40. 20–34/OR
41. 35 AND 36 AND 37 and 38
42. Limit 39 to Humans
43. Limit 40 to >16 years old

Search 2

1. Name of Identified functional performance test (example: Y balance test)
2. Lower extremity.mp.
3. exp lower extremity/
4. exp lower limb/
5. hip.mp
6. knee.mp
7. ankle.mp
8. foot.mp
9. exp anterior cruciate ligament
10. exp acl
11. exp lateral ankle ligament
12. exp chronic ankle
13. injury.mp.

Continued

Box 1 Continued

14. exp injury/
15. ligament injuries.mp
16. joint instability.mp
17. strain/sprain.mp
18. exp strain/sprain
19. Athlete.mp.
20. exp Athlete/
21. validity.mp
22. exp validation studies/
23. reliability.mp
24. exp reproducibility of results/
25. interpretability.mp
26. internal consistency.mp
27. exp sensitivity and Specificity/
28. clinical sensitivity.mp
29. exp psychometrics/
30. responsiveness.mp
31. exp Evaluation studies/
32. measurement error.mp
33. measurement properties.mp
34. 42–53/OR
35. 54–59/OR
36. 60 OR61
37. 62–74/OR
38. 75 AND 76 AND 77 AND 78
39. Limit 79 Humans
40. Limit 80 to >16 years old

all potential eligible studies will then be screened independently (RC & LH) with a third reviewer (NRH) acting as a mediator in the event of disagreement. Agreement by reviewers at first and second review will be assessed by kappa statistic using previously reported levels of 0.40–0.59 fair, 0.60–0.74 good and 0.75 or more as excellent agreement.⁷⁴

Data collection process

Data will be extracted independently by one reviewer for search 1 (RC) and two reviewers (RC and LH) from the articles identified in search 2. The data extraction form will be trialled on three randomly selected papers from search 2 to ensure that all relevant information is collected. Contact with authors will be made via email if required. This will be to seek clarification on FPT methodology or for raw data to enable further analysis such as calculation of measurement error.⁷⁴

Data items

Table 3 summarises the data items that will be extracted from the full-text articles.

Risk of bias in individual studies

The COSMIN risk-of-bias checklist⁷⁵ will be used to assess methodological quality of measurement properties within individual studies. Two reviewers (RC and LH) will independently assess included studies from searches 1 and 2. In the event of disagreement, a third reviewer (NRH) will mediate the decision. For each

study, the checklist will be used to assess the methodological quality for each measurement property separately. Each measurement property will be rated as very good, adequate, doubtful or inadequate quality.^{71 76} The overall methodological quality of individual studies for each measurement property will be rated based on ‘the worst score counts principle’.⁷¹ The ratings for each measurement property per individual study, as well as the overall rating of the individual study, will be presented in the final results.⁷¹

Data synthesis

In line with COSMIN guidelines for systematic reviews,⁷¹ the results will be quantitatively pooled or qualitatively summarised for each measurement property, and grouped per each FPT. FPT protocols may demonstrate variation between studies, and therefore FPT will be grouped by movement task. An overall rating of these pooled or summarised results will be assessed using the updated criteria for good measurement properties⁷⁶ as sufficient (+), insufficient (–) or indeterminate (?). The quality of evidence will be assessed using the modified GRADE approach.⁷¹ Summary of findings tables will be used to present these results. Where possible a random effects meta-analysis will be conducted on the pooled estimates of different studies (minimum of 2) for each measurement property using the DerSimonian-Laird method.⁷⁷ In the presence of high heterogeneity where $I^2 > 75\%$,⁷⁸ further analysis will be considered using the following subgroups, (1) specific athlete cohort, for example, female, (2) injury diagnosis for example, ACL, (3) lower extremity anatomical location (foot, ankle, knee and hip) and (4) sport.

If quantitative pooling is not possible due to limited numbers of studies or high heterogeneity, qualitative summarising of the results will be completed and report information such as range of scores for minimally important change (MIC) to assess interpretability.⁷¹ For the summarised results to be considered sufficient, at least 75% of the results must meet the criteria for good measurement properties.⁷⁶ The overall rating of the pooled or summarised result will be added to the summary of findings table per measurement property per FPT.

For an FPT to be recommended for use in profiling athletes, it must demonstrate sufficient content validity and at least low-quality evidence for sufficient internal consistency.⁷¹

Practicability of the FPT is an essential criterion as well as the quality of the measurement properties associated with it. For this review practicability will be assessed by two reviewers with extensive experience of completing FPT with elite athletes and will include factors relating to the interpretability (complexity of FPT scoring, minimal detectable change and MIC) and feasibility (test duration, equipment required, cost, scoring and completion complexity).^{39 79}

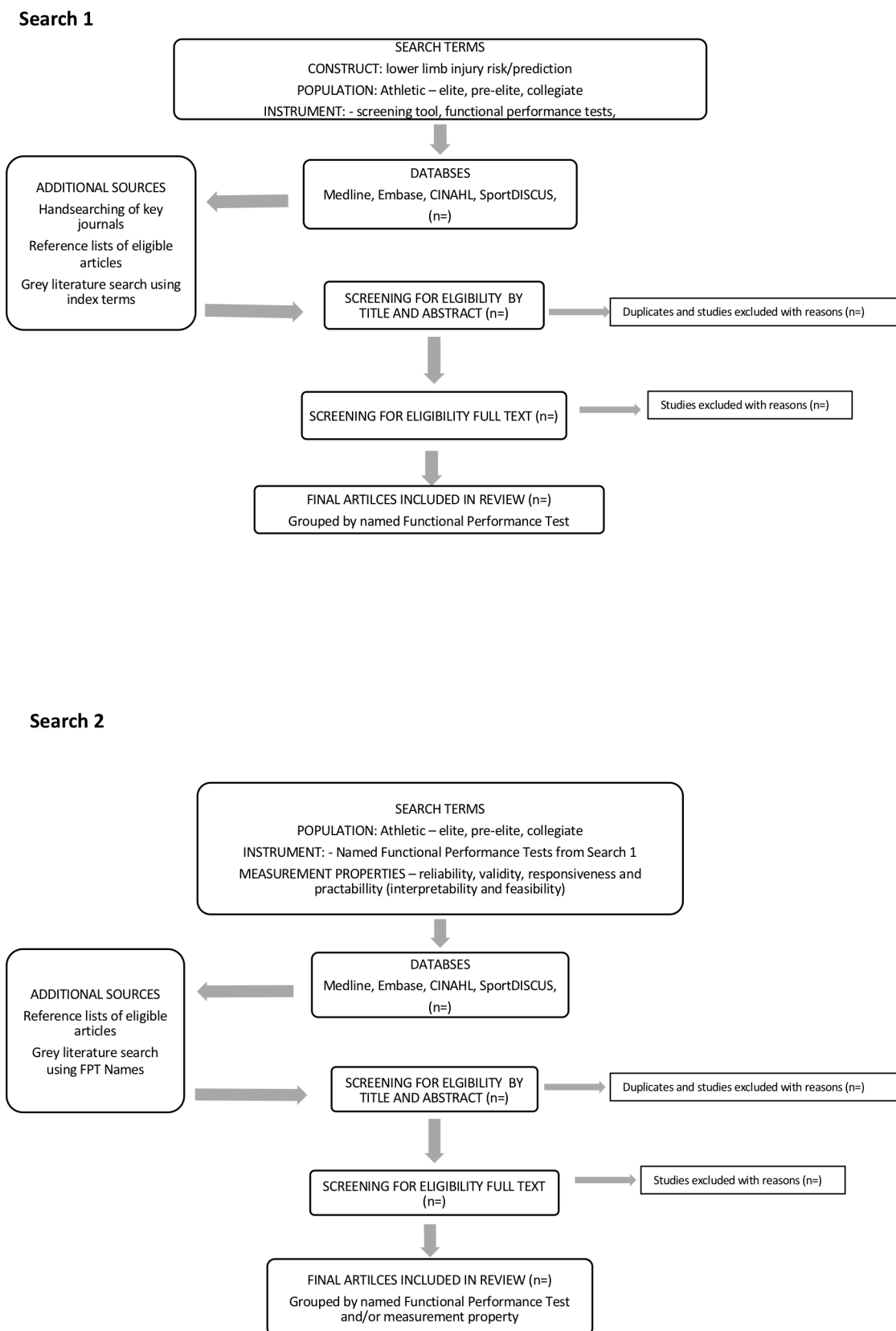


Figure 1 Flow chart of search strategy and study selection process.

Confidence in cumulative evidence

A modified GRADE approach⁷¹ will be used to assess the overall body of evidence for the measurement properties of the identified FPT. This approach differs from

the original GRADE criteria and only uses the following factors as its basis of assessment: (1) risk of bias (quality of studies), (2) inconsistency (of the results of the studies), (3) indirectness of evidence (differences in population,

Table 3 Data items for extraction: search 1 and search 2

Search	Data items		
Searches 1 and 2	Study	Reference Year Country of origin Study design	
	Population	Athletic level (elite, pre-elite, collegiate) Gender Sport/s	
	FPT	Name of test Setting of test use Equipment required Training required Mode of administration Scoring of test Demonstrated prospective evaluation of ability to indicate risk of or predict lower limb injury Which lower limb injuries has the FPT indicated/predicted	
	Search 2 Only and when reported	Validity	Type of validity FPT development or validation study Comparator outcome or predicted outcome Descriptive statistics of population Results of FPT Statistical methods Correlation coefficient
		Reliability	Type of reliability, Time interval Descriptive statistics Measurement error
		Responsiveness	Responsiveness ratio Effect size Standardised response mean
		Interpretability	MIC SEM MDC Floor or ceiling effects At risk cut-off value Applicability across sports and athletes Clinical Significance
		Feasibility	Time taken to screen athlete, Ease of standardisation, Ease of score calculation, Copyright of FPT, Cost of instrument/equipment

FPT, functional performance tests; MDC, minimal detectable change; MIC, minimally important change; SEM, SE of measurement.



construct than ones of interest in the review) and (4) imprecision of effect estimates (wide CIs). The fifth factor used in the GRADE approach assesses publication bias which is not included by the COSMIN methodology due to the lack of registry for measurement properties.⁷¹ This process will be completed by two reviewers (RC and LH) with the support of a third reviewer (NRH) to achieve consensus if required.

DISCUSSION

FPT assess an individual's ability to perform movement patterns and adapt to multiplanar forces that are similar to those experienced during sporting activity.^{37 45–53} The ability to assess this outside of the biomechanics laboratory provides practitioners and researchers with low tech, low cost options to profile large numbers of athletes at regular time intervals.^{40–45} Being able to identify those athletes at risk enables targeted injury-prevention programmes to be implemented.^{30 39 45 61 65 67}

FPT for the lower extremity have been used in a variety of contexts in both non-injured and rehabilitation populations with different methodologies. In light of this, there is a need for a specific review to identify which FPT identify athletes at risk of LEI, assess the measurement properties of these FPT, and report their quality and practicability.

This review through its comprehensive and robust methods will seek to synthesise the available evidence for FPT in this context. The anticipated outputs from this review will recommend FPT which have the ability to identify individuals at risk of sustaining an LEI. As this review considers a specific population and using FPT to prospectively predict injury the number, variability in FPT test protocol and methodological quality of the available studies may limit the potential for meta-analysis. To overcome this limitation a comprehensive narrative synthesis informed by the available results on measurement properties will be completed and priorities for future research will be reported.

Implications of study

Previous LEI predisposes athletes to future injury which results in further time loss from training and competition compromising their sporting potential or even leading to their retirement from sport.^{20–23} Identifying those athletes at risk of sustaining an LEI is a priority and FPT offer the ability to profile athletes without the requirements for high cost, time intensive laboratory-based testing.^{40–45}

A systematic review is needed to evaluate which FPT have the ability to identify athletes at risk of LEI. The results of this review will enable practitioners and researchers to select the best available FPT based on their measurement properties and practicability. The results of this review may also highlight the need to optimise or standardise FPT testing protocols and results reporting to address deficits in measurement properties as well as enable a comparison between different athletic cohorts.

Amendments

Any changes to this protocol will be reported in the final review as well as detailed on PROSPERO. Information will include the date, the changes and the rationale for these.

ETHICS AND DISSEMINATION

No ethics approval is required for this systematic review. The results of this systematic review will be disseminated through peer-reviewed journals as well as international and national conferences presentation.

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Contributors All authors conceptualised and designed the protocol. RC is a PhD student and NRH (lead supervisor), AR, JM and LH are supervisors. RC drafted the initial manuscript with NRH, AR, JM and LH providing guidance on design, topic, methodology and analyses. All authors reviewed and commented on each draft of the protocol. All authors have approved and contributed to the final manuscript.

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