**Version2**

**Kinetic measurement systems in Individuals Following Anterior Cruciate Ligaments Reconstruction: A Scoping Review Protocol**

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**INTRODUCTION**

An anterior cruciate ligament (ACL) rupture is a devastating injury that frequently occurs in sports.1 Anterior cruciate ligament reconstruction (ACLR) is often recommended to restore joint stability and minimize potential damage to articular cartilage and menisci.2 It has been reported that the proportion of individuals who return to competitive levels following ACLR is 55% (95%CI: 46%-63%) while 81% (95%CI: 46%-63%) return to any sport.3 However, up to 38% of elite athletes reduce their participation levels or stop their career within three years after ACLR.4 Moreover, 20%-25% of post-ACLR individuals experience a re-rupture or a contralateral ACL injury.5

A variety of test batteries have been designed to inform RTS decisions.6,7 These include isokinetic strength assessment, hop tests, and other self-reported functional outcome measures.8,9 Evidence suggests that passing RTS criteria significantly reduces the risk of re-injury;10 however, the validity of current RTS testing protocols have been increasingly questioned.

Kinetic measurement systems have emerged as measuring instruments to objectively assess different movement tasks such as jumping and landing,11 postural control,12,13 gait,14 and other biomechanical parameters.15 These systems use specific transducers to measure three-dimensional forces exerted upon them.16 They are utilized by clinicians and researchers to assess functional progression throughout rehabilitation and may predict the ability to RTS in post-ACLR individuals.17 Previous studies have examined various kinetic parameters in relation to the odds of secondary ACL injury or RTS;17 however, there is a lack of consistency in the literature about what parameters to assess and what assessment protocol to follow in a population of individuals following primary ACLR.

Thus, the primary objectives of this scoping review are to (1) describe the approaches for kinetic measurements in individuals following primary ACLR and (2) propose methodological reporting considerations for future studies. The secondary objective is to examine how commonly kinetic measurement system findings were related to PROMs. This review will provide clinicians and researchers with further information on the use of kinetic measurement systems in the ACLR population and may also inform future studies which, ultimately, may assist in advancing this field of study.

**METHODS**

**Protocol design**

This scoping review will be conducted according to the six stages methodology framework proposed by Arksey and O'Malley (2005, Table 1)18 and revised by Levac et al. (2010).19 Besides, we will consult the Joanna Briggs Institute Manual for scoping Review.20 It will include papers that report on different parameters measured by force plates (outcome) in individuals with primary ACLR (exposure).

The PRISMA Extension for Scoping Reviews (PRISMA-ScR) will guide the development of this protocol and the reporting of the final scoping review.21

Table Arksey and O'Malley 5-stage methodological framework18

|  |  |
| --- | --- |
| Stage 1 | Identify the scope and inquiries |
| Stage 2 | Identify data sources and search |
| Stage 3 | Record screening and study selection |
| Stage 4  | Data charting |
| Stage 5  | Collate, summarize, analyze and report the results |
| Stage 6 | Stakeholders' consultation |

**Study team**

To reduce a potential source of bias and facilitate robust and relevant clinical review findings,22 the multidisciplinary study team included individuals with various expertise in research methodology, epidemiology, evidence synthesis, sport and exercise therapy, knee injuries rehabilitation, kinesiology, and engineering.19

**Stage 1: Identifying the scope and inquiries**

The research questions that will guide this scoping review are:

What are the current approaches for kinetic measurements in individuals following ACLR?

Is there a need to propose methodological reporting considerations for future studies?

**Participants (population):** This review will consider studies that included participants from different ages, sexes, sports and activity levels.

**Concept:** The review will include studies that reported at least one kinetic parameter that was calculated solely based on a kinetic measurement system data.

**Context:** Only studies that include extractable data of individuals who were at least 6 months following a primary ACLR (i.e., following completion of standard rehabilitation) will be considered.

**Eligibility Criteria**

All inclusion and exclusion criteria are reported in Table 2

Table Inclusion and Exclusion Criteria

|  |  |
| --- | --- |
| Inclusion Criteria | Exclusion Criteria  |
| Human participants | Animal models or cadavers |
| * Primary study design (quantitative & mixed methods) with original published data
 | * Qualitative studies and not primary study design or original data (conference proceedings or abstracts, editorials, commentaries, opinion-based papers and systematic, scoping, or narrative reviews)
* Case Studies
 |
| * Studies with participants post-ACLR
 | * Studies with participants post-ACL repair (i.e., surgical reattachment of the ACL, instead of performing a reconstruction) 23
 |
| * Studies with a population of primary ACLR participants
 | * Studies with only secondary ACLR participants
* Studies where participants have other significant comorbidities, including; musculoskeletal, neurologic and/or systemic disorders
* Studies where more than 50% of the participants had meniscal procedures at the same time as the ACLR
 |
| * Studies with kinetic measurement systems outcomes
 | * Studies with no kinetic measurement systems outcomes. Studies that included force plates only to confirm foot contact with ground (confirmatory kinetic measurement system)
 |
| * Only studies with extractable data of individuals who were at least 6 months following a primary ACLR (i.e., following completion of standard rehabilitation) were considered
 | * Reported data before 6 months post-ACLR
 |

Table Definitions

|  |  |
| --- | --- |
| *Participants* | Any individual with primary ACLR with no limitation to a specific age group, sex, or activity level.  |
| *Primary ACLR* | A first time ACLR; surgical tissue graft replacement of the anterior cruciate ligament to restore its function after injury.24  |
| *Kinetic measurement systems* | This review included all platforms that use similar kinetic measurement systems technologies including force plates, balance platforms, pressure platforms, force measuring treadmills, Wii balance boards, contact mats connected to jump systems (computer software or device), and single-sensor insoles. |

**Stage 2: Identifying data sources and search**

**Information sources**

We will identify potentially relevant studies through searching electronic databases including; MEDLINE (Medical Literature Analysis and Retrieval System Online), EMBASE (Excerpta Medica dataBASE), CINAHL (Cumulative Index of Nursing and Allied Health Literature), SPORTDiscus, Scopus, Web of Science, and ProQuest Dissertations and Theses Global for unpublished theses. We will search all databases since inception with no language limitations

**Search strategy**

We will determine and refine search terms through an iterative process with inputs from the study team, knowledge users, and research collaborators.18,19 The search strategy will be developed in consultation with an experienced librarian scientist (LD). It will be revised according to meetings outputs with the study team and stakeholders to ensure relevant records will be captured. The search terms will combine keywords and subject headings (MeSH) that have emerged in this research field, as appropriate. (Appendix 1)

**Stage 3: Record screening and study selection**

Database search results will be exported into a reference management software EndNote X9.3.3. Duplicates will be removed.25 The titles and corresponding abstracts of remaining records will be independently reviewed by two raters blinded to author(s) and journal title using Covidence (Veritas Health Innovation, Melbourne, Australia; available at [www.covidence.org](http://www.covidence.org)). Prior to the title and abstract reviews, raters will independently screen a random sample of 100 titles and abstracts to assess the applicability of the exclusion criteria and to determine the Cohen Kappa score and inter-rater agreement with the first author (WL) using a Microsoft® Excel workbook explicitly designed for screening.26 Based on the pilot screening, the study team will meet to further clarify the exclusion criteria before commencing title and abstract screening. Finally, two independent raters will perform the full-text review to determine final study selection. Any further disagreement on study eligibility during the title and abstract screening and the full-text review stages will be resolved through discussion between the two reviewers, and a third reviewer will be approached if necessary, until a consensus is reached. The results of the search will be reported in full in the final review report and will be presented in the PRISMA flowchart.

**Stage 4: Data Charting**

In consultation with the study team members, the primary author (WL) will develop a data collection templet using Covidence. Data items to be extracted are summarized in (Table 4). The study team will review the instrument. It will be pretested by two independent reviewers on a pilot of 10 studies to ensure the tool is capturing the information accurately. Two reviewers will independently extract data in duplicate. To ensure accurate data extraction, each of the two forms will be compared for discrepancies and will be further discussed until consensus is reached. A third reviewer will be consulted if needed. The data will be extracted using a Google Sheet

A decision regarding quality appraisal of the included studies will be made following full text reviewing and will be dependent upon the quantity and type of literature identified.

Table Data Items

|  |  |
| --- | --- |
| Category | Item(s) |
| Study characteristics | Author(s), year of publication, study design and location |
| Study objectives |  |
| Sample characteristics | Sample size disaggregated by sex, age and physical activity/sport |
| Primary ACL | Graft used and time after surgery |
| Force plate outcomes | Testing procedure(s) used to estimate different outcomes. Estimates of parameters identified in individual following ACLR, with inter-limb comparison and/or compared to healthy controls. The validity and reliability of the measurement methods.  |
| Study quality appraisal | Downs and Black Checklist for the assessment of the methodological quality27score |
| Level of evidence | Oxford Centre of Evidence-Based Medicine (OCEBM) 2011 model28 |

**Stage 5: Collate, summarize, analyze and report the results**

The analysis of the data items in the data-charting framework will provide us with information on the current approaches for kinetic measurements in individuals following ACLR. Our results may also highlight the emergence of different uses for force platforms as clinical or research utilities. Conversely, the review may show areas that have been understudied and recommend future research. The results will be presented in a way that relates to the review's questions and objectives of this scoping review using tables and charts, as appropriate. Descriptive and numerical analysis of the extracted variables will explain and discuss how the results align with the predetermined research objectives.

**Stage 6: Consultation**

To employ an integrated knowledge translation and dissemination approach, we will engage knowledge users for their inputs on the study findings.

In addition to the on-going consultation with the multidisciplinary study team, other knowledge partners and collaborators will also be approached. We will consult them for their perspectives on the study findings. To employ an integrated knowledge translation, we will prepare a presentation disseminating our preliminary findings to other health care professionals at Glen Sather Sports Medicine Clinic, participate in conferences, and publish our final report in a peer-reviewed journal.

**CONCLUSION**

This protocol forms the cornerstone to a scoping review on the current approaches for kinetic measurements in individuals following ACLR. The study will advance the knowledge of the utility of kinetic measurement systems in the assessment of post-ACLR individuals and identify potential gaps in the body of evidence. Moreover, this review will examine the feasibility of conducting a future systematic review or meta-analysis.

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**Appendix 1- Search Strategies**

**Ovid MEDLINE(R) ALL 1946 to June 04, 2020**

Date searched: June 5, 2020

Results: 1194

1. exp anterior cruciate ligament reconstruction/

2. ((Anterior cruciate ligament or ACL) adj8 (repair or reconstruct\* or surgery or post-operativ\* or postoperativ\*)).mp.

3. 1 or 2

4. (forceplate\* or force plate\* or force platform\* or balance platform\* or balance board\* or wii balance or unstable platform or KAT-2000 or KAT2000 or platform system or biodex stability system or biodex balance system or centre of gravity or center of gravity or Neruocom balance master or Kistler or GRF or GRFs or VGRF or VGRFs or ground reaction force\* or kinetic\* or center of pressure).mp.

5. (Reactive strength index-modified or RSImod or vertical impulse or rate of force development or force production or jump duration or flight time or peak force\* or fatigue index or reactive strength index or limb-impulse\* or phase specific or knee-extensor-power or muscle-power or time curve).mp.

6. (postural stability or postural instability or postural balance or postural control or postural sway or postural impairment\* or dynamic balance or dynamic stability or dynamic control or static balance or static stability or static control or standing balance or balance impairment\* or stabilometric).mp.

7. (functional-test\* or quiet standing or hop test or single leg hop or single leg squat or landing or (jump adj2 height) or ((Bilateral or unilateral or countermovement or squat or drop or vertical) adj4 jump\*) or ((Leg or legs or limb or limbs or knee or knees or functional or strength or muscle or index or indices) adj4 (asymmetr\* or symmetr\*))).mp.

8. 3 and (or/4-7)

9. limit 8 to (address or autobiography or bibliography or biography or clinical trial, veterinary or clinical trials, veterinary as topic or dictionary or directory or editorial or interview or news or newspaper article or observational study, veterinary)

10. 8 not 9

**Embase 1974 to 2020 June 04 (OVID interface)**

Date searched:June 5, 2020

Results: 1268

1. anterior cruciate ligament reconstruction/

2. ((Anterior cruciate ligament or ACL) adj8 (repair or reconstruct\* or surgery or post-operativ\* or postoperativ\*)).mp.

3. 1 or 2

4. (forceplate\* or force plate\* or force platform\* or balance platform\* or balance board\* or wii balance or unstable platform or KAT-2000 or KAT2000 or platform system or biodex stability system or biodex balance system or centre of gravity or center of gravity or Neruocom balance master or Kistler or GRF or GRFs or VGRF or VGRFs or ground reaction force\* or kinetic\* or center of pressure).mp.

5. (Reactive strength index-modified or RSImod or vertical impulse or rate of force development or force production or jump duration or flight time or peak force\* or fatigue index or reactive strength index or limb-impulse\* or phase specific or knee-extensor-power or muscle-power or time curve).mp.

6. (postural stability or postural instability or postural balance or postural control or postural sway or postural impairment\* or dynamic balance or dynamic stability or dynamic control or static balance or static stability or static control or standing balance or balance impairment\* or stabilometric).mp.

7. (functional-test\* or quiet standing or hop test or single leg hop or single leg squat or landing or (jump adj2 height) or ((Bilateral or unilateral or countermovement or squat or drop or vertical) adj4 jump\*) or ((Leg or legs or limb or limbs or knee or knees or functional or strength or muscle or index or indices) adj4 (asymmetr\* or symmetr\*))).mp.

8. 3 and (or/4-7)

9. limit 8 to conference abstract status

10. 8 not 9

11. limit 10 to editorial

12. 10 not 11

**CINAHL Plus with Full Text (EBSCOhose interface)**

Date searched: June 5, 2020

Results: 966

S1 (MH "Anterior Cruciate Ligament Reconstruction") OR ( (Anterior cruciate ligament or ACL) N8 (repair or reconstruct\* or surgery or post-operativ\* or postoperativ\*)) )

S2 forceplate\* or force-plate\* or force-platform\* or balance-platform\* or balance-board\* or wii-balance or unstable-platform or KAT-2000 or KAT2000 or platform-system or stability-system or balance-system or centre-of-gravity or center-of-gravity or balance-master or Kistler or GRF or GRFs or VGRF or VGRFs or ground-reaction-force\* or kinetic\* or center-of-pressure or centre-of-pressure or Reactive-strength-index-modified or RSImod or vertical-impulse or rate-of-force-development or force-production or jump-duration or flight-time or peak-force\* or fatigue-index or reactive-strength-index or limb-impulse\* or phase-specific or knee-extensor-power or muscle-power or time-curve or postural-stability or postural-instability or postural-balance or postural-control or postural-sway or postural-impairment\* or dynamic-balance or dynamic-stability or dynamic-control or static-balance or static-stability or static-control or standing-balance or balance-impairment\* or stabilometric or functional-test\* or quiet-standing or hop-test or single-leg-hop or single-leg-squat or landing or (jump N2 height) or ((Bilateral or unilateral or countermovement or squat or drop or vertical) N4 jump\*) or ((Leg or legs or limb or limbs or knee or knees or functional or strength or muscle or index or indices) N4 (asymmetr\* or symmetr\*))

S3 S1 AND S2

S4 S3 Limiters - Publication Type: Biography, Book Review, Editorial, Obituary, Pamphlet, Pamphlet Chapter, Proceedings

S5 S3 NOT S4

**SPORTDiscus with Full Text (EBSCOhose interface)**

Date searched: June 5, 2020

Results: 846

S1 ( ( (Anterior cruciate ligament or ACL) N8 (repair or reconstruct\* or surgery or post-operativ\* or postoperativ\*)) ) AND ( forceplate\* or force-plate\* or force-platform\* or balance-platform\* or balance-board\* or wii-balance or unstable-platform or KAT-2000 or KAT2000 or platform-system or stability-system or balance-system or centre-of-gravity or center-of-gravity or balance-master or Kistler or GRF or GRFs or VGRF or VGRFs or ground-reaction-force\* or kinetic\* or center-of-pressure or centre-of-pressure or Reactive-strength-index-modified or RSImod or vertical-impulse or rate-of-force-development or force-production or jump-duration or flight-time or peak-force\* or fatigue-index or reactive-strength-index or limb-impulse\* or phase-specific or knee-extensor-power or muscle-power or time-curve or postural-stability or postural-instability or postural-balance or postural-control or postural-sway or postural-impairment\* or dynamic-balance or dynamic-stability or dynamic-control or static-balance or static-stability or static-control or standing-balance or balance-impairment\* or stabilometric or functional-test\* or quiet-standing or hop-test or single-leg-hop or single-leg-squat or landing or (jump N2 height) or ((Bilateral or unilateral or countermovement or squat or drop or vertical) N4 jump\*) or ((Leg or legs or limb or limbs or knee or knees or functional or strength or muscle or index or indices) N4 (asymmetr\* or symmetr\*)) )

S2 S1 Limiters - Publication Type: Audio, Audiocassette, CD-ROM, Computer Disk or Diskette, Conference Proceeding, Newspaper, Newswire, Proceeding, Trade Publication, Video, Video Recording, Videocassette, URL

S3 S1 NOT S2

**SCOPUS**

Date searched:June 5, 2020

Results: 1395

TITLE-ABS-KEY ( ( anterior-cruciate-ligament OR acl ) W/8 ( repair OR reconstruct\* OR surgery OR post-operativ\* OR postoperativ\* ) ) AND TITLE-ABS-KEY ( forceplate\* OR force-plate\* OR force-platform\* OR balance-platform\* OR balance-board\* OR wii-balance OR unstable-platform OR kat-2000 OR kat2000 OR platform-system OR stability-system OR balance-system OR centre-of-gravity OR center-of-gravity OR balance-master OR kistler OR grf OR grfs OR vgrf OR vgrfs OR ground-reaction-force\* OR kinetic\* OR center-of-pressure OR centre-of-pressure OR reactive-strength-index-modified OR rsimod OR vertical-impulse OR rate-of-force-development OR force-production OR jump-duration OR flight-time OR peak-force\* OR fatigue-index OR reactive-strength-index OR limb-impulse\* OR phase-specific OR knee-extensor-power OR muscle-power OR time-curve OR postural-stability OR postural-instability OR postural-balance OR postural-control OR postural-sway OR postural-impairment\* OR dynamic-balance OR dynamic-stability OR dynamic-control OR static-balance OR static-stability OR static-control OR standing-balance OR balance-impairment\* OR stabilometric OR functional-test\* OR quiet-standing OR hop-test OR single-leg-hop OR single-leg-squat OR landing OR ( jump W/2 height ) OR ( ( bilateral OR unilateral OR countermovement OR squat OR drop OR vertical ) W/4 jump\* ) OR ( ( leg OR legs OR limb OR limbs OR knee OR knees OR functional OR strength OR muscle OR index OR indices ) W/4 ( asymmetr\* OR symmetr\* ) ) ) AND ( EXCLUDE ( DOCTYPE , "cp" ) OR EXCLUDE ( DOCTYPE , "no" ) OR EXCLUDE ( DOCTYPE , "ed" ) )

**Web of Science** Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI

Date searched: June 5, 2020

Results: 1259

TS=( ( anterior-cruciate-ligament OR acl ) NEAR/8 ( repair OR reconstruct\* OR surgery OR post-operativ\* OR postoperativ\* ) ) AND TS=( ( anterior-cruciate-ligament OR acl ) NEAR/8 ( repair OR reconstruct\* OR surgery OR post-operativ\* OR postoperativ\* ) ) AND DOCUMENT TYPES: (Article OR Book OR Book Chapter OR Correction OR Data Paper OR Letter OR Note OR Retracted Publication OR Retraction OR Review)

Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=All years

**Dissertations and Theses Global(Proquest interface)**

Date searched:June 5, 2020

Results: 118

noft(((anterior-cruciate-ligament OR acl) NEAR/8 (repair OR reconstruct\* OR surgery OR post-operativ\* OR postoperativ\*))) AND (forceplate\* or force-plate\* or force-platform\* or balance-platform\* or balance-board\* or wii-balance or unstable-platform or KAT-2000 or KAT2000 or platform-system or stability-system or balance-system)