OPTIKNEE 2022: consensus recommendations to optimise knee health after traumatic knee injury to prevent osteoarthritis

Jackie L Whittaker ,[1,2,3] Adam G Culvenor ,[4] Carsten Bogh Juhl,[5,6] Bjørnar Berg ,[7,8] Alessio Bricca ,[6,9] Stephanie Rose Filbay ,[10] Pætur Holm,[6,9] Erin Macri,[11,12,13] Anouk P Urhausen ,[14] Clare L Ardern,[4,11] Andrea M Bruder ,[4] Garrett S Bullock ,[15] Allison M Ezzat ,[1,4] Michael Girdwood ,[4] Melissa Haberfield ,[4] Mick Hughes,[16] Lina Holm Ingelsrud ,[17] Karim M Khan ,[11,18] Christina Y Le ,[2,19] Justin M Losciale ,[1,2] Matilde Lundberg,[20] Maxi Miciak ,[19] Britt Elin Øiestad ,[21] Brooke Patterson ,[4] Anu M Räisänen ,[3,22] Søren T Skou ,[6,9] Jonas Bloch Thorlund ,[6,20] Clodagh Toomey,[23] Linda K Truong ,[1,2] Belle L. van Meer ,[24] Thomas James West ,[4] James Justin Young ,[6,25] L Stefan Lohmander ,[26] Carolyn Emery ,[3,27,28] May Arna Risberg,[7,14] Marienke van Middelkoop ,[12] Ewa M Roos ,[6] Kay M Crossley [4]

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bjsports-2022-106299).

For numbered affiliations see end of article.

Correspondence to
Dr Jackie L Whittaker, Department of Physical Therapy, The University of British Columbia, Vancouver, BC V6T 1Z3, Canada; jackie.whittaker@ubc.ca

JLW and AGC are joint first authors.
EMR and KMC are joint senior authors.

Accepted 29 October 2022
Published Online First 15 November 2022

To cite: Whittaker JL, Culvenor AG, Juhl CB, *et al*. *Br J Sports Med* 2022;**56**:1393–1405.

ABSTRACT

The goal of the OPTIKNEE consensus is to improve knee and overall health, to prevent osteoarthritis (OA) after a traumatic knee injury. The consensus followed a seven-step hybrid process. Expert groups conducted 7 systematic reviews to synthesise the current evidence and inform recommendations on the burden of knee injuries; risk factors for post-traumatic knee OA; rehabilitation to prevent post-traumatic knee OA; and patient-reported outcomes, muscle function and functional performance tests to monitor people at risk of post-traumatic knee OA. Draft consensus definitions, and clinical and research recommendations were generated, iteratively refined, and discussed at 6, tri-weekly, 2-hour videoconferencing meetings. After each meeting, items were finalised before the expert group (n=36) rated the level of appropriateness for each using a 9-point Likert scale, and recorded dissenting viewpoints through an anonymous online survey. Seven definitions, and 8 clinical recommendations (who to target, what to target and when, rehabilitation approach and interventions, what outcomes to monitor and how) and 6 research recommendations (research priorities, study design considerations, what outcomes to monitor and how) were voted on. All definitions and recommendations were rated appropriate (median appropriateness scores of 7–9) except for two subcomponents of one clinical recommendation, which were rated uncertain (median appropriateness score of 4.5–5.5). Varying levels of evidence supported each recommendation. Clinicians, patients, researchers and other stakeholders may use the definitions and recommendations to advocate for, guide, develop, test and implement person-centred evidence-based rehabilitation programmes following traumatic knee injury, and facilitate data synthesis to reduce the burden of knee post-traumatic knee OA.

EXECUTIVE SUMMARY

To promote knee health and prevent post-traumatic osteoarthritis (PTOA), we recommend that clinicians:

- Prioritise people with single and multi-structure intra-articular knee injuries who have symptoms and/or functional restrictions persisting beyond usual recovery times, or have a subsequent knee injury.
- Provide person-centred interventions to promote education, self-management, and exercises that mitigate known modifiable risk factors for re-injury and non-traumatic OA—commencing as soon as possible after injury and continuing across the lifespan.
- Focus ACL tear management on education and exercise-therapy-based rehabilitation, with optional reconstruction if a patient cannot achieve their acceptable functional level. Rehabilitation should be initially supervised and progress through semi-supervised to unsupervised self-care and include weight bearing, mobility, open and closed kinetic chain resistance, neuromuscular control and plyometric exercises targeting the quadriceps and hamstring muscles. Rehabilitation should also prioritise return to activity preparation, and techniques to promote exercise engagement and knee health self-management.
- Monitor knee pain and other symptoms, adverse events, knee-related quality of life and cognitive behavioural factors (fear, self-efficacy and confidence), self-reported knee function, quadriceps and hamstring muscle function (strength), functional performance (hop battery) and physical activity/sport participation.

To better understand how to promote knee health and prevent PTOA, we recommend that researchers:

- Prioritise symptomatic over structural knee PTOA (including reaching consensus on how to define and measure both) and understand how social determinants of health influence PTOA development.
- Design studies, including participants with ACL tear and/or non-ACL tear related knee injuries, and assess PTOA risk and rehabilitation interventions with follow-up beyond 5 years.
- Monitor knee pain and other symptoms, adverse events, knee-related quality of life, cognitive behavioural factors, physical function (including self-reported function, muscle function and functional performance), physical activity/sport participation and participant global assessment.

INTRODUCTION

Traumatic knee injuries are very common, occurring in 720–1800 per 100 000 persons annually.[1 2] Injury frequency varies by sex/gender, age and precipitating event, with the highest incidence in adolescents and young adults[3] participating in sport and recreational activities.[4 5] Traumatic knee injuries are associated with short-term (eg, negative mood states, re-injury anxiety, loss of social identity,[6] withdrawal from sport,[7] physical inactivity[8 9] and long-term (eg, obesity,[10] reduced quality of life[11 12] and osteoarthritis (OA)[13]) negative health outcomes. Specifically, these injuries are linked to a 6-fold increased risk of radiographic OA at 11 years,[14] and 6-fold elevated lifetime risk of arthroplasty.[15 16] Due to their relatively young injury age, people with traumatic knee injuries develop OA at an earlier age than to those without injuries, leading to more years lived with disability.[17]

Knowing that traumatic injuries precipitate knee OA presents an opportunity to prevent (delay or halt) OA. This opportunity hinges on knowing who develops post-traumatic OA (PTOA; target population), when and how to intervene (target treatments), and what are the most important outcomes and methods to assess them.[18]

No clinical recommendations are available to guide interventions that might prevent symptomatic PTOA. Care pathways for people with knee injuries vary widely by practitioner, setting, diagnostic testing completed, surgery(s) performed, length/content of care and payment model.[19] Importantly, people at-risk of PTOA rarely seek or receive care promoting risk awareness or knee health.[20–22] From a research perspective, heterogeneity in OA definitions, outcome domains and measures, prevents synthesis of results across the field.[23 24]

OPTIKNEE is an international group of clinician scientists, scientists, and patient and clinician partners working to optimise knee and overall health after a traumatic injury to prevent symptomatic knee PTOA. After multiple planning meetings (2017–2019) and a priority setting exercise in 2019 (Toronto, Canada), the OPTIKNEE group embarked on a consensus process. This paper reports the consensus process and its results: definitions and recommendations to guide clinical rehabilitation practice and research aimed at informing, developing, evaluating and implementing rehabilitation interventions to improve knee and overall health-related outcomes following a traumatic knee injury.

METHODS

Design and reporting

The OPTIKNEE consensus followed a seven-step hybrid approach guided by the RAND UCLA Appropriateness Method (RAM)[25] and Nominal Group Technique[26] (figure 1). The RAM is an established approach explicitly developed to leverage expert opinion in situations where evidence may be incomplete, while the Nominal Group Technique provides a structured approach to face-to-face meetings to facilitate widespread engagement of all participants. Reporting was informed by the Appraisal of Guidelines for Research and Evaluation statement (AGREE II)[27] and Conducting and REporting of DElphi Studies[28] as appropriate. Box 1 outlines the methods for each consensus step including expert group selection. All systematic review protocols and consensus materials are freely available on the Open Science Framework at https://osf.io/7tfxn/.

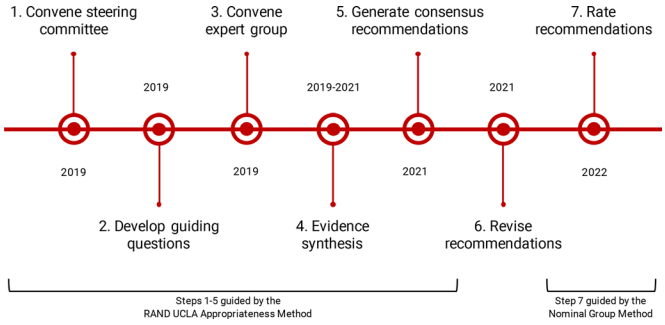


Figure 1 OPTIKNEE seven-step consensus approach.

Patient and public involvement

One individual with lived experience of ACL tear (and ACL reconstruction (ACLR)) and four clinicians (ie, physiotherapists and orthopaedic surgeons) contributed to the priority theme setting for the OPTIKNEE consensus. One patient partner and one clinician (sports and exercise medicine physician) were authors on the risk factor review,[29] and one additional patient and clinician partner provided feedback on one of the intervention reviews.[30] A patient partner and a clinician (physiotherapist) provided feedback on this manuscript.

Mitigation

Consensus exercises can be vulnerable to persuasion (bias) by the steering group[31] and dominant personalities,[32] lack generalisability and inadvertently suppress contrary opinions that may be vital for moving the field forward.[33] Several steps were taken to mitigate these potential downfalls. Steering committee members did not participate in the small group conversations and only contributed to the full group discussions during the consensus meetings when invited, there was a need for clarification, or when they sought guidance from the larger group. We engaged an experienced external moderator (CLA) and used small group discussions, to mitigate the influence of dominant personalities and support all expert group members to contribute. Finally, the unique perspectives of the expert group members contributed to exploring each definition and recommendation through varied lenses.

Role of funding source

The initial priority setting exercise was funded by a Canadian Institutes of Health Research Planning and Dissemination grant (principal investigator JLW #161821). No financial support was received for the systematic reviews or consensus.

Dissemination plan

After the consensus voting was complete, we engaged a 'knowledge broker' (a person who promotes interaction between researchers and end users)[34] to develop and execute a

Box 1 Consensus methods

1. Convene steering committee (September 2019)
   - Steering committee convened after a 2019 priority setting exercise* hosted by JLW, EMR and KMC.
   - Members included a balance of early (JLW and AGC) and later career (EMR and KMC) clinician scientists, from 3 continents, with expertise in knee injury and OA who had undertaken groundwork for the consensus since 2016.
   - One committee member specifically recruited for expertise in evidence synthesis (CBJ).
2. Develop guiding questions (September 2019)
   - To meet the consensus objectives, the steering committee developed five guiding questions:
     1. What is the burden of traumatic knee injuries?
     2. What are the risk factors for symptomatic and structural knee PTOA?
     3. What rehabilitation approaches and interventions should be used to prevent knee PTOA?
     4. What PROs can monitor important outcomes from traumatic knee injury to PTOA?
     5. What functional tests can monitor important outcome from traumatic knee injury to PTOA?
3. Convene Expert group (October–December 2019)
   - 6 experts (CAE, SF, MAR, BEØ, EMM and MvM) were asked to co-lead a systematic review related to a guiding question (review leads).
   - Review leads identified other experts for their review teams, including as possible, a patient and a clinician partner.
   - Equity, Diversity and Inclusion: Experts were selected on their research activities related to traumatic knee injury and PTOA. Gender equity and diversity of career stage, race and geographical location was sought. Clinical rehabilitation experience in the field was viewed favourably.
4. Evidence synthesis to address guiding questions (August 2020–November 2021)
   - Single systematic reviews were conducted to address the burden, risk factor and PROs questions, while the intervention and functional outcomes questions were addressed in two reviews each.
   - Review protocols were registered on the Open Science Framework† (7 August 2020). The Cochrane Handbook[1] informed conduct, and the PRISMA guidelines[2] and PRISMA-Search extension,[3] informed reporting.
   - Search strategies developed with a librarian scientist, consistent across the population construct (traumatic knee injury and mean or median injury age ≤30 years)‡. All reviews, except the risk factor review, focused on ACL and/or meniscal tears to reflect the majority of evidence. For the risk factor review, the population was expanded to evaluate PTOA risk across all knee injury types.
   - Risk-of-bias across included studies was assessed, and when appropriate, certainty of evidence rated.
   - Table 1 summarises review topics, objectives, synthesis type, risk-of-bias tools and certainty of evidence approach for each review.
   - Steering committee members and review leads met (video conferencing§) every 4-6 weeks (~1 hour) over the review protocol development and conduct stage to ensure consistency in conduct, provide methodological support, and navigate barriers encountered.
5. Generate consensus recommendations (November–December 2021)
   - Consensus recommendations were generated through an iterative process.
   - Review groups submitted clinical recommendations and research recommendations, each accompanied by a statement of supporting evidence.
   - Steering committee members reviewed recommendations, and when needed, requested additional recommendations based on other evidence sources including other systematic reviews, expert consensus, high quality original studies and/or expert opinion.
   - Clarity of draft recommendations were discussed during a videoconferencing meeting with review leads, refined and finalised¶. Draft definitions for commonly used terms across the recommendations were developed by the steering committee to ensure consistency and to facilitate discussions.¶
6. Revise recommendations (January–May 2022)
   - Draft definitions and recommendations were discussed during 6, 2-hour videoconferencing sessions and revised for voting.**
   - Before meetings, expert group members reviewed the intent of the definitions or recommendations¶, an evidence summary¶ and relevant OPTIKNEE systematic review(s).
   - At the start of each meeting attendees were reminded of the consensus goals, context (secondary prevention of PTOA) and guiding principles (inclusive respectful conversations, solution focused comments).
   - Each meeting included a presentations of definitions or recommendations and supporting evidence; small group breakout room discussions (~6/group); small group discussion summaries to the full group; full group discussion and summary.
   - Discussions were focused on the meaning and/or dissenting views of the definitions or recommendations.
   - Meetings were recorded, and facilitated by an expert external moderator (CLA).[4 5] Small group discussions were led by expert group members, supported by a trainee (shared common definitions or recommendations slides and recorded breakout room interaction). Each small group prioritised specific definitions or recommendations to ensure all were discussed equally, but also discussed other items as time permitted.
   - After small groups shared their feedback, the full group elaborated on, or raised new discussion points. Experts could contribute to the discussion by using the raise hand or chat function, and key points were compiled using a real-time collaborative platform.††
   - After meetings, review leads and the steering committee incorporated the feedback and finalised the definitions and recommendations for voting.**
7. Rate recommendations (February–June 2022)

Continued

Box 1 Continued

- Within 2-3 weeks of each meeting, the steering committee and expert group were sent an anonymous link to an online survey‡‡ to rate the level of appropriateness and record comments/dissenting viewpoints, for the definitions or recommendations discussed.
- Level of appropriateness was based on a 9-point Likert scale (1 = not appropriate and 9 = most appropriate).[6] Scores were pooled and items with a median score of 1–3 were considered inappropriate, 4–6 uncertain and 7–9 appropriate as per the RAM.[6] Variability of voting was categorised as small (≤3 points), moderate (4–5 points) and large (≥6 points).

*Open Science Framework Sharing Page.
†https://osf.io/7tfxn/.
‡With the exception of the Burden systematic review which did not restrict based on age of injury.
§Zoom.
¶Seee online supplemental file 1.
**See online supplemental file 3.
††Padlet.
‡‡REDCap.
ACL, anterior cruciate ligament; GRADE, Grading of Recommendations Assessment, Development and Evaluation;, OA, osteoarthritis; PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses; PROs, patient-reported outcomes; PTOA, post-traumatic osteoarthritis; RAM, RAND UCLA Appropriateness Method.

dissemination plan to increase awareness and catalyse adoption of the recommendations among patients, healthcare providers, researchers and other stakeholders (eg, sports organisations and clubs, athletic associations, funding agencies, scholarly societies and healthcare funders).

RESULTS

Expert group demographics

The expert group (n=36) of 33 clinician scientists (29 physiotherapists, 2 sport and exercise medicine physicians, 1 orthopaedic surgeon and 1 chiropractor), and 3 scientists (sports science and kinesiology) included 21 women, 15 men and 1 of undisclosed gender with a mean (SD) age of 41 (12) years. Thirty three either currently or previously had, a patient caseload, and 15 had lived experience of a traumatic knee injury. The group spanned career stages (10 professor or professor emeritus, 3 associate professor, 6 assistant professor, research fellow, instructor, or research associates and 17 trainees, including 1 Master, 8 PhD and 7 post-doctoral fellows) and 9 countries (10 Australia, 8 Canada, 5 Denmark, 5 Norway, 2 Netherlands, 3 USA, 2 Sweden, 1 Ireland and 1 Italy), and was predominantly white (92% white, 5% southeast Asian, 2% west Asian and 1% other). All experts were fluent in English. Individual involvement at each stage is outlined in the online supplemental file 2.

Evidence synthesis

The seven systematic reviews we conducted to synthesise the evidence (table 1), incorporated the findings of approximately 230 studies containing data from >133 000 persons with traumatic knee injuries.[17 29 30 35–38] Of the seven systematic reviews, four performed quantitative syntheses, and all seven performed semi-quantitative or narrative syntheses.

Definitions

Twenty-six definitions were developed to facilitate discussions. Eight definitions (ie, rehabilitation, prevention, structural and symptomatic knee OA, knee injury, knee PTOA and early-onset knee PTOA) represented core consensus concepts and were discussed at the first consensus meeting. The remaining 17 definitions were provided to the expert group for reference (see online supplemental file 3). One draft core definition (pre-PTOA) was removed after discussion, because it replicated the concept of 'at-risk'. The remaining 7 core definitions were deemed appropriate with agreement ranging from 7 to 9 (table 2). Voting distribution and dissenting viewpoints are summarised in the online supplemental file 3.

Recommendations

Figures 2–4 contain the 8 clinical (with 30 subcomponents) and 6 research (with 19 sub-components) recommendations, and a summary of their appropriateness based on expert group voting. A detailed summary of the supporting evidence, voting results and all dissenting viewpoints for all recommendations can be found in online supplemental file 3. The recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Symptomatic PTOA was prioritised over structural PTOA, given that pain, disability and impaired quality of life drive the burden of OA and the variable relationship between structure and symptoms. High level themes that unite the recommendations include an expanded focus beyond ACL tears, the complementary nature of exercise-based and surgical interventions, a lifespan approach to mitigating knee PTOA risk and person-centred approach.

Clinical recommendations: the 8 clinical recommendations address who to target, when and how to target and what outcomes to monitor to manage traumatic knee injuries and mitigate the burden of symptomatic knee PTOA. The certainty of evidence for the clinical recommendations ranged from expert opinion to a GRADE (Grading of Recommendations Assessment, Development and Evaluation)[39] rating of moderate (burden, risk factors and interventions) or high (patient-reported outcomes (PROs), strength tests and functional performance tests). GRADE is a method for rating the certainty of evidence and strength of a recommendation.[40] All eight recommendations were rated as appropriate except for two subcomponents related to adjunct treatments (blood-flow restriction training and whole-body vibration) to improve quadriceps strength after an ACL tear or ACLR, which were rated as uncertain (figures 2 and 3). The median (minimum–maximum) agreement across the clinical recommendations was 9 (4.5–9).

Research recommendations: the 6 research recommendations address priorities for knee injury and PTOA research, study design considerations and what outcomes to monitor. One additional draft recommendation (how to interpret outcome changes) was removed after the consensus meeting, because there was insufficient evidence available to inform a recommendation.[36–38]

Table 1 Overview of systematic reviews

Topic	Objective(s)	Synthesis type	RoB and certainty of evidence tools
Burden of traumatic ACL or meniscal tear[17]	Primary: synthesise evidence on physical activity, work limitations, health/economic costs, disease burden, and HRQoL outcomes ≥2 years after traumatic ACL and/or meniscal injury Secondary: determine the burden of living with knee symptoms and OA after traumatic ACL and/or meniscal injury	Meta-analyses Narrative	RoB: NIHQAT[34] Certainty: GRADE[50]
Risk factors for knee OA after traumatic knee injury[29]	Primary: identify and quantify the magnitude of potential modifiable and non-modifiable risk factors for symptomatic and structural knee OA following a traumatic knee injury	Meta-analyses and semi-quantitative	RoB: QUIPS[51] Certainty: GRADE approach for prognostic factor reviews[52]
Rehabilitation after traumatic ACL and meniscal tear: clinical outcomes[30]	Primary: critically appraise and synthesise systematic review evidence of RCTs assessing rehabilitation interventions following ACL and/or meniscal tear to improve symptomatic, functional, clinical, psychosocial or quality of life outcomes and prevent re-injury	Narrative	RoB: ROBIS tool[53] Certainty: GRADE[54]
Rehabilitation after traumatic ACL and meniscal tear: structural and molecular biomarkers[35]	Primary: synthesise existing RCT evidence of different management strategies and rehabilitation approaches to ACL and/or meniscal tear on structural and molecular biomarkers of knee joint health	Narrative	RoB: Cochrane ROB 2.0 tool[1] Certainty: GRADE[43]
Meaningful thresholds for patient reported outcomes for traumatic ACL or meniscal tear[36]	Primary: identify, critically appraise and synthesise estimates for thresholds defining meaningful PROs scores for use with individuals treated for a traumatic ACL tear and/or meniscal injury	Meta-analyses Narrative	Credibility: MIDCAT[55]
Measurement properties of functional performance tests following traumatic ACL or meniscal tear[38]	Primary: synthesise and critically appraise the measurement properties of functional performance tests in individuals following ACL and/or meniscal tear	Meta-analyses Narrative	RoB: COSMIN checklist[48 56] Certainty: GRADE approach for PROs[57]
Measurement properties of muscle strength tests following traumatic ACL or meniscal tear[37]	Primary: synthesise and critically appraise the measurement properties of knee extensor and flexor strength in individuals following ACL and/or meniscal tear	Meta-analyses Narrative	RoB: COSMIN checklist[48 58] Certainty: GRADE approach for PROs[57]

ACL, anterior cruciate ligament; COSMIN, COnsensus-based Standards for the selection of health Measurement INstruments; GRADE, Grading of Recommendations Assessment, Development and Evaluation approach; HRQoL, health-related quality of life; MIDCAT, Minimal Important Difference Credibility Assessment Tool; NIHQAT, National Institute of Health Quality Assessment Tools; OA, osteoarthritis; PROs, patient-reported outcomes; QUIPS, Quality in Prognosis Studies; RCT, randomised controlled trial; ROB, risk-of-bias; ROBIS, Risk of Bias In Systematic reviews.

Instead, guidance on interpreting changes in recommended PROs, muscle function and functional performance tests is provided in online supplemental file 4, and recommendation on thresholds for minimal important change, patient acceptable symptom state and treatment failure are summarised in the PROs systematic review.[36] The certainty of evidence for the research recommendations ranged from expert opinion to a GRADE[39] rating of moderate (burden, risk factors and interventions) or high (PROs, strength tests and functional performance tests). All 6 recommendations and subcomponents voted on were deemed appropriate (figure 4), with the median (minimum–maximum) agreement across recommendations of 9 (7–9). Voting distribution and dissenting viewpoints are summarised in the online supplemental file 3.

DISCUSSION

The OPTIKNEE consensus meetings produced 8 clinical and 6 research recommendations. We encourage clinicians to integrate the clinical recommendations alongside their own expertise, individual patient preferences and available resources (eg, time and equipment) to provide best-practice care (Box 2). Clinician scientists and researchers can leverage the research recommendations and dissenting viewpoints to conduct rigorous and transparent research to propel the field of knee injury rehabilitation and PTOA prevention forward. These recommendations can also empower patients to advocate for person-centred evidence-based treatments, and to increase awareness about preventing the long-term consequences of traumatic knee injuries among other stakeholder groups.

Clinical implications and call to action

Decades of research have established that traumatic knee injuries increase the risk of OA. Despite this, widespread clinical actions to promote knee health have not been implemented. There are many barriers to preventative healthcare for knee PTOA. Front-line healthcare providers tend to focus on acute knee injury recovery and return to activity/work/sport, and rarely prioritise their role in preventing knee PTOA or other long-term consequences. To complicate matters, people who experience knee injuries rarely understand their risk for OA, nor seek or receive care beyond the precipitating knee injury.[20–22] More broadly, there is a lack of high level evidence and until now, consensus guidelines to guide treatment decisions. This has left clinicians guessing about whom to target, when and how to intervene and what outcomes to monitor.

The OPTIKNEE clinical recommendations are an important first step in overcoming barriers to prevent knee PTOA. The recommendations highlight the elevated risk for PTOA across people with a variety of traumatic knee injuries (including but beyond an ACL tear) and the need to promote knee and overall health in all patients. Considering the resource constraints of the clinical setting, the recommendations highlight PROs that assess multiple outcome domains (useful when time is limited) and single outcome domains (useful when deeper understanding is needed), and guidance on how to assess and interpret muscle function and functional performance when sophisticated equipment is, and is not, available. The recommendations highlight exercise-based interventions as core first-line treatments for knee injuries and PTOA prevention, and the importance of equipping patients with the knowledge and skills to self-manage their knee

Table 2 Core definitions and voting results

Word		Definition	Median	Minimum–maximum	Mode	Appropriateness	Votes
D1.	Rehabilitation	A health strategy aimed at enabling people with a health condition reach and maintain their optimal physical, sensory, intellectual, psychological and social functional levels. It does so by providing them with the tools needed to attain independence and self-determination.*	8	7–9	8	Appropriate	34
D2.	Prevention	Activities that mitigate modifiable risk factors for disease/illness. These activities can focus on reducing the risk of disease†/illness in healthy individuals (primary prevention), early identification and reducing progression to disease or illness in individuals at high risk or with preclinical disease/illness (secondary prevention), or improving function and reducing disability in persons diagnosed with a disease/illness (tertiary prevention). In the context of OPTIKNEE, prevention refers to identifying and reducing progression from 'at-risk' to PTOA diagnosis in persons who have had a traumatic knee joint injury (secondary prevention).	8.5	5–9	9	Appropriate	34
D3.	Structural knee OA	Knee OA defined by the presence of structural features on imaging, or arthroscopy, which reach an established expert or consensus threshold of magnitude and character to be termed OA (eg, Kellgren and Lawrence grade, MRI-defined OA based on the MRI Osteoarthritis Knee Score and ICRS cartilage score).	9	7–9	9	Appropriate	34
D4.	Symptomatic knee OA	Knee OA defined by consensus-based clinical signs and symptoms (eg, ACR, NICE and EULAR definitions), excluding age restrictions, with or without the presence of structural features identified on imaging or arthroscopy.	9	7–9	9	Appropriate	34
D5.	Knee injury	Knee joint tissue damage or derangement resulting from a rapid or repeated transfer of kinetic energy.	8.5	5–9	9	Appropriate	34
D6.	Knee PTOA	Structural or symptomatic OA that develops following a traumatic knee joint injury.	9	4–9	9	Appropriate	34
D7.	Pre-PTOA	This definition was removed after the consensus meeting, because it was felt that it was captured by the concept of 'at-risk'.					
D8.	Early-onset knee PTOA	Symptomatic or structural knee PTOA that develops in youth and young adults (ie, young people with old knees). Note: similar in concept to 'early-onset' as in 'early-onset' dementia.	7	3–9	7	Appropriate	34

*Adapted from Cochrane Group: https://rehabilitation.cochrane.org.
†OA disease refers to the underlying biology and pathophysiology of OA characterised by structural alterations of the articular cartilage and subchondral bone[59 60]
‡OA illness refers to an individuals' feeling, or experience of OA characterised by pain, functional impairments, muscle weakness, joint stiffness and reduced quality of life[59 60]
ACR, American College of Rheumatology; ICRS, International Cartilage Research Society; NICE, National Institutes for Health and Care Excellence; OA, osteoarthritis; PTOA, post-traumatic osteoarthritis.

health over their lifespan. Finally, as exercise is a behaviour, the recommendations recognise several behaviour change techniques,[41] including goal setting (goal-based criteria), feedback on exercise (early supervision and semi-supervision) and social support (a collaborative therapeutic alliance and person-centred approach) as important for promoting exercise engagement.[42]

The clinical recommendations may not be as prescriptive as some may desire, due to a paucity of evidence. For example, the recommendations do not include a menu of specific exercises or detailed exercise dosages to reduce the risk of knee symptoms and PTOA. Instead, general principles that point to the value of resistance-based, neuromuscular control and plyometric exercises can be used to develop personalised exercise-based programmes.[43–45] Clinicians can feel confident about the safety of open and closed chain exercises that target the quadriceps and hamstrings, and neuromuscular electrical stimulation to promote quadriceps strength. In contrast, the expert group recommends caution for the routine use of both blood-flow restriction training, and whole-body vibration to improve quadriceps strength, and against use of continuous passive motion, and knee bracing.

We expect the OPTIKNEE clinical recommendations will spark debate. Surfacing dissenting viewpoints among the expert group (see online supplemental file 3) is a strength of quality consensus statements,[33 46] and can promote shared decision-making with stakeholders (eg, patients). Expert group dissent centred around how to operationalise the decision that a patient has completed sufficient rehabilitation and should consider ACLR; the value of bracing early post-surgery to restrict motion (meniscal repair) or promote weight-bearing (ACLR) and to temper fear or anxiety of movement; and the feasibility of single domain PROs, hop test battery and formal muscle function (strength, endurance and power) testing in clinical settings.

Research implications and call to action

To move the field of PTOA prevention forward, unique challenges to study design and data synthesis need to be overcome. Some of the biggest hurdles are a lack of a standardised definition of early PTOA, the need for lengthy follow-up to assess for the development and/or progression of PTOA, and adequate participant retention and/or sample sizes to ensure sufficient participants to control for confounding factors (eg, injury type, injury management and physical activity). Data synthesis, which is a solution to the sample size barrier, is currently impeded by variability in outcomes measures, and the tests or instruments

Clinical Recommendation*	Appropriateness Rating ✓ ? X
C1. WHO to target to prevent PTOA People with single **(a)** and multi-structure **(b)** injuries (particularly ACL tears, meniscal tears, intraarticular tibiofemoral fractures, and patellar dislocations with concomitant chondral lesions)**(c)**. **Prioritise** people with symptoms and/or functional impairments that persist beyond usual recovery times, or with a subsequent injury ^**(d).**	a b c d
C2. WHAT and WHEN to target to prevent PTOA Promote knee health through education^ **(ai)**, self-management^ **(aii)**, mitigating known modifiable risk factors for re-injury and non-traumatic OA^ **(aiii)**, and person-centred goals^ **(aiv)**. **Start** these efforts as soon as possible after injury **(bi)** and continue across the lifespan **(bii)**.	ai aii aiii aiv bi bii
C3. WHAT TO DO after an ACL tear† **First-line ACL tear treatment** includes education^ and exercise-therapy-based rehabilitation **(a)**. Delay the decision to undergo ACLR until there is a quiet knee^. The decision to have an ACLR should be made by the patient (informed by relevant stakeholders^) if they cannot achieve their acceptable functional level despite sufficient muscle function^ **(b).** **ACL tear and ACLR rehabilitation** incorporates patient preferences, is goal and/or criterion-based, and begins with supervised,^ then semi-supervised home (gym)-based rehabilitation to unsupervised home (gym) self-management **(c)**. **Core components of ACL tear and ACLR exercise-based rehabilitation** include: • Weight-bearing, mobility, open and closed kinetic chain resistance-based, neuromuscular control and plyometric lower-limb exercises^ (including neuromuscular electrical stimulation to improve quadriceps strength **(ei)**; return to work, sport or other physical activity preparation; techniques to promote exercise adherence and self-management of knee health^; and cognitive behavioural techniques as appropriate^ **(d)**. • Adjunct treatments for improving quadriceps strength include blood-flow restriction training **(eii)**, and whole-body vibration **(eiii)**. **ACL tear and ACLR Rehabilitation DOES NOT** include continuous passive motion **(fi)**, or knee bracing **(fii)**. **Return to pivoting sport criteria** after ACL tear or ACLR includes being ≥9 months post-ACL tear or ACLR and passing a test battery^ **(g)**.	a b c d ei eii eiii fi fii g
C4. WHAT TO MONITOR after a traumatic knee injury‡ **Core clinical outcomes** include: **knee-related** pain, symptoms other than pain^, adverse events (e.g. subsequent injury, giving way)^, cognitive behavioural factors that influence learning and performance^, physical function (e.g., self-reported function, functional performance and/or muscle function), QOL, and **overall** physical activity and sport participation^ **(ai-vii)**. **Other important clinical outcomes** can include**:** body weight, health-related QOL, participation in social roles, responsibilities and relationships (e.g., occupation, care-giving community participation)^, and injury-related mental health (e.g., depression, anxiety)^ **(bi-iv)**. **Diagnostic imaging** is only indicated when results will inform treatment planning **(c)**.	ai aii aiii aiv av avi avii bi bii biii biv c

Figure 2 Clinical recommendations 1–4 and appropriateness rating. *See online supplemental file 3) for level of supporting evidence, results of expert group appropriateness voting and dissenting viewpoints for all recommendations (and components). ^See online supplemental file 4, for example. †Applicable to patients who have had an ACL tear and/or undergone an ACLR but may not apply to every individual and situation. The patient and healthcare provider should consider the unique features of a patient's injury, the resources available to them and their unique situation when developing a treatment plan. ‡Choice of domain(s) will vary based on individual presentation, goals and practicality. Appropriateness rating: ✓ = recommendation is appropriate (median scores: ≥7/9), ? = recommendation is uncertain (median scores: 4–6), X = recommendation is not appropriate (median scores: 1–3). ACL, anterior cruciate ligament; ACLR, ACL reconstruction; OA, osteoarthritis; PTOA, post-traumatic osteoarthritis; QOL, quality of life.

we use. Perhaps, most importantly, much of the research in the field of traumatic knee injuries and PTOA has focused on structural and molecular definitions of OA, when symptomatic OA drives the individual and societal burden. This disconnect leaves us with a limited understanding of the mechanisms underlying symptomatic PTOA.

The OPTIKNEE research recommendations are an important step to overcome the barriers that interfere with conducting PTOA prevention research and data synthesis. To enhance understanding of clinical trajectories following traumatic knee injury, the recommendations advocate to include patient groups beyond those with an ACL tear treated with ACLR, emphasise the importance of symptomatic definitions of PTOA, and need to follow patients for at least 5 years (if possible) from time of injury. To facilitate data synthesis, the recommendations include a core group of outcome domains, other important domains and current best methods to assess those domains based on their measurement properties, including interpretability.

Despite including information from ~230 individual studies in the OPTIKNEE systematic reviews, many of the clinical recommendations were based on very-low certainty of evidence or expert opinion (in the absence of empirical evidence). What is often missing is the information to translate evidence into the clinical setting or to act beyond knee injury to mitigate PTOA risk. For example, we have identified unmodifiable risk factors for knee PTOA, but not modifiable risk factors (ie, treatment targets)[29 35] for poor prognosis or PTOA. While we have a sense of what evidence-based care is for ACL tears, we are unclear if these approaches are appropriate for other injury types (eg, meniscal tears) or if they mitigate PTOA risk.[30 35] We also do not understand which outcomes are the most useful to monitor across the timespan from injury to PTOA and what constitutes a meaningful change in an outcome.[36–38] These knowledge gaps represent important targets for future research and should be pursued alongside patient partners using existing study design and reporting guidelines to ensure higher levels of certainty of evidence and facilitate data synthesis (eg, PROGRESS 2,[18] CONSORT, CERT[47] and COSMIN).[48]

A new approach to consensus

Consensus has been defined as 'a formal process that aims to derive recommendations on a topic when evidence is NOT available'.[32 49] As the definition implies, consensus is founded on understanding what evidence exists and what gaps remain. By identifying and making recommendations to bridge these gaps, consensus can unify and guide clinical practice, inspire discourse, push researchers to be more strategic and collaborative and combine collective resources to overcome the barriers.[33]

Several unique design features of our consensus process included our hybrid approach (eg, RAM[25] and Nominal Group Technique)[26]; broad guiding questions that required extensive evidence-synthesis; iterative process to develop and revise consensus definitions and recommendations; use of multiple short meetings instead of a traditional singular meeting and videoconferencing. Some features were planned 'a priori' (hybrid methods, broad guiding questions and extensive evidence-synthesis), while others were driven by necessity due to COVID-19 pandemic travel restrictions (multiple short meetings and videoconferencing). Others evolved out of opportunities that presented themselves (thorough and thoughtful recommendation iteration).

Clinical Recommendation*	Appropriateness Rating ✓ ? X
C5. HOW TO MONITOR PATIENT-REPORTED OUTCOMES after a traumatic knee injury[a]	
Core clinical patient-reported outcomes to choose from to monitor MULTIPLE domains include **(a)**: • IKDC-SKF (composite score of knee-related symptoms, function and sports activities) • KOOS (composite score AND single domain scores for knee pain, other symptoms, function in daily living, function in sport/recreation, QOL) • WOMET (overall composite score of knee-related physical symptoms, sports/recreation/work/lifestyle, and emotions: meniscal only)	a bi bii
Other clinical patient-reported outcomes to choose from to monitor SINGLE domains include: • Pain: Numerical Rating Scale or Visual Analogue Scale **(bi)** • Knee-related QOL: ACL QOL Score **(bii)** • Health-related QOL: Visual analogue scale^, or SF-12 **(biii)** • Knee-related cognitive behaviour factors: ACL-RSI Scale, K-SES, or TSK-11 **(biv)** • Physical activity and sport participation: sport resumption and frequency^ **(bv)** • Participation in social roles, responsibilities and relationships: occupation, caregiving and community^ **(bvi)** • Injury-related mental health: anxiety and depression^ **(bvii)**	biii biv bv bvi bvii
C6. HOW TO MONITOR MUSCLE FUNCTION[b] after a traumatic knee injury	
Core clinical knee muscle function measures include: peak thigh muscle (knee extensor/flexor) strength **(a)**.	a bi bii
Clinical measures of peak knee extensor/flexor strength include[c] (as available): • Computerized dynamometry (concentric isokinetic contraction at ≥60°/s) **(bi)** • Hand-held dynamometry (isometric maximum effort)[c] **(bii)** • Weight machine (concentric isotonic 1RM knee extension or knee flexor curl) **(biii)**	biii ci cii d
Other important muscle function measures include: thigh muscle endurance **(ci)** and power **(cii)**, and trunk, hip, and leg muscle function **(d)**.	
C7. HOW TO MONITOR FUNCTIONAL PERFORMANCE[d] after a traumatic knee injury	
Core clinical functional performance measures include: hopping **(a)**.	
Clinical measures to estimate hop performance include[e]: a battery **(bi)** of forward (single and repeated), diagonal and/or vertical hop **(bii)** tests.	a bi bii
Core clinical hop tests include: • Crossover hop (diagonal) **(ci)** • Single hop (single-forward) **(cii)** • Triple-hop (ciii) and 6m timed hop (repeated-forward) **(civ)** • Vertical hop (vertical) **(cv)**	ci cii ciii civ cv d
Other important clinical measures of functional performance include: balance, agility or other tasks meaningful to the patient^ **(d)**.	
C8. HOW TO INTERPRET PATIENT-REPORTED, MUSCLE FUNCTION, AND FUNCTIONAL PERFORMANCE To **interpret the change (a)** and **current state (b)** of an outcome, ask a patient if they have noticed a meaningful change, and if their current state is acceptable/satisfactory. To better **understand a patient's experience** of an outcome, ask about individual PRO item^ responses **(c)**. **Record** the baseline and follow-up score, and direction of change (either improvement or deterioration) in the outcome(s) **(di)**, if the patient felt the change was meaningful **(dii)**, and if they feel that their current state of that outcome is acceptable/satisfactory^ **(diii)**.	a b c di dii diii

Figure 3 Clinical recommendations 5–8 and appropriateness rating. *See online supplemental file 3 for level of supporting evidence, results of expert group appropriateness voting and dissenting viewpoints for all recommendations (and components). ^See supplementary file for examples. appropriateness rating: ✓ = recommendation is appropriate (median scores: ≥7/9), ? = recommendation is uncertain (median scores: 4–6) and X = recommendation is not appropriate (median scores 1–3). [a]Instrument choice will vary by individual presentation, goals, practicality, and instrument availability. domains and instruments are presented alphabetically. Licencing requirements may apply but might be available through an employer. [b]The capacity of a muscle to do work (eg, strength, power and endurance). [c]Strength tests should only be performed when safe. Isometric scores are not interchangeable with isokinetic or isotonic scores. As hand-held dynamometry can underestimate strength, it is important to secure the femur, have the patient push into resistance generated by a fixed belt and for re-assessment to be conducted by the same assessor. 1RM should be based on the average of at least two measures of maximum effort. [d]The action of carrying out or accomplishing a movement, movement task or movement activity. [e]Hop tests should only be performed when safe. Test choice may be influenced by individual presentation, goals, practicality, and availability of space. Test is presented in alphabetical order as there is insufficient evidence to inform the 'best' test or 'best' order. ACL, anterior cruciate ligament; ACL-QOL, ACL quality-of-life score; ACLR, ACL reconstruction; ACL-RSI, ACL Return to Sport after Injury Scale; IKDC-SKF, International Knee Documentation Committee Subjective Knee Form; K-SES, Knee Self-Efficacy Scale; KOOS. Knee Injury and Osteoarthritis Outcome Score; PTOA, post-traumatic osteoarthritis; QOL, quality of life; RM, repetition maximum; TSK, Tampa Scale of Kinesiophobia; WOMET, Western Ontario Meniscal Evaluation Tool.

The most unique feature was that the consensus meeting was broken into short (2 hour) meetings spread out over several months compared with a more traditional one-off intensive multiday meeting. This provided experts ample time to prepare for individual topics and engage in a more fulsome discussion without the fatigue that can set in during 'marathon' meetings. The time between meetings also allowed for considerable reflection, which we believe led to more mature recommendations which most in the expert group found highly appropriate. We also identified benefits associated with the use of videoconferencing. In particular, the small group discussions (virtual breakout rooms), large group discussions and chat function provided multiple opportunities and means to engage experts in the conversation. A skilled moderator was essential to mitigating the bias of any dominant personalities. Finally, the use of a real-time collaborative platform (Padlet) helped to reduce redundancy in conversations and gave experts the confidence that their feedback was recorded and would be taken into consideration as the definitions and recommendations were revised in preparation for voting.

Strengths of the consensus process include an extensive evidence-synthesis, open access to *a priori* systematic review protocols and consensus materials, reproducible and structured approach to consensus and voting, mitigation strategies to address dominant personalities, and confidential rating by experts. Despite deliberate efforts to generate diversity within the expert panel (ie, gender, race, geography and career stage) we acknowledge that we lack perspectives of persons from racial groups and from middle to low-income countries. Considered alongside the fact that most of the primary studies included in the systematic reviews were conducted in high-income countries, the recommendations may have limited applicability beyond white communities and middle- to low-income countries. Whenever possible the recommendations include freely available resources (ie, PROs) and less resource intensive options (ie, strength and functional performance testing). The perspectives of patients,

Research Recommendation*	Appropriateness Rating ✓ ? X
R1. PRIORITIES for knee injury and knee PTOA OA research **Prioritise** symptomatic knee PTOA[a] with or without the presence of structural features, over structural PTOA **(a)**. Reach **consensus** on how to **define, measure and report** symptomatic and structural knee PTOA to facilitate data synthesis **(b)**. Assess the association between **social determinants of health** (including sex, gender, race), and PTOA to understand disparities **(c)**.	a b c
R2. STUDY DESIGN to identify risk factors for PTOA, and assess rehabilitation interventions after a traumatic knee injury **Include** participants with ACL tear (including ACL deficient) and/or non-ACL tear related injuries **(a, d)**. **Report** structural knee OA overall and by medial tibiofemoral, lateral tibiofemoral and patellofemoral joint compartments **(b)**. **Conduct** RCTs of rehabilitation interventions with follow-up >5 years to assess the effect on symptomatic and structural knee PTOA **(c)**.	a b c d
R3. WHAT OUTCOME DOMAINS TO MONITOR[b] after a traumatic knee injury **Core research outcome domains** include: **knee-related** pain, other symptoms^, adverse events (e.g., subsequent injury, giving way), cognitive behavioural factors^, physical function (e.g., self-reported, performance-based, muscle function)^, QOL, and **overall** physical activity and sport participation^ and participant global assessment **(ai-viii)**. **Other important research outcome domains** include: adiposity, health-related QOL, injury-related costs, comorbidities, participation in social roles (e.g., occupation, care-giving, community participation)^, imaging (structural) and molecular biomarkers, and injury-related mental health (e.g., anxiety, depression)^ **(bi-vii)**. **Consider monitoring outcomes** across the timespan from injury to OA diagnosis **(c)**.	ai aii aiii aiv av avi avii aviii bi bii biii biv bv bvi bvii c
R4. HOW TO MONITOR PATIENT-REPORTED OUTCOMES[b] after a traumatic knee injury **Core research PROs** include: $KOOS_{Pain}$, NRS or VAS (knee pain); $KOOS_{Symptoms}$ (other knee symptoms); ACL-RSI Scale, K-SES, or TSK-11 (knee cognitive behaviour factors); $KOOS_{SportRec}$ (knee physical function); ACL QOL Score, or $KOOS_{QOL}$ (knee QOL); sport resumption and frequency (physical activity and sport participation)^, GROC, PASS or Treatment Failure Score (participant global assessment) **(ai-avii)**. **Research PROs for other single domains** include: EQ-5D Index, SF-12 or SF-36 (health-related QOL); occupation, caregiving and community (participation in social roles)^; injury-related anxiety and depression (injury-related mental health)^ **(bi-biii)**. **Research PROs for multiple domains** include: IKDC-SKF[c], KOOS[d], or WOMET[e] **(biv)**.	ai aii aiii aiv av avi avii bi bii biii biv
R5. HOW TO MONITOR MUSCLE FUNCTION[f] after a traumatic knee injury **Core research knee muscle function measures** include: peak thigh muscle (knee extensor/flexor) strength **(a)**. **Research measures of knee extensor/flexor strength** (most to least rigour), include[g]: computerized dynamometry (concentric isokinetic contraction ≥60°/s), HHD (isometric max effort)^ or weight machine (concentric isotonic 1 RM knee extension or knee flexor curl) **(bi-biii)**. **Other important research measures of knee muscle function** include: thigh muscle endurance **(ci)**, power **(cii)**, morphology **(ciii)**, and neurophysiology **(civ)**, and function of the lower leg, hip and trunk muscles **(d)**.	a bi bii biii ci cii ciii civ d
R6. HOW TO MONITOR FUNCTIONAL PERFORMANCE[h] after a traumatic knee injury **Core research measures of functional performance** include: hop performance **(a)**. **Research measures of hop performance** include[i]: battery of forward (single and repeated), diagonal and/or vertical hop tests **(bi-bii)**. **Core research hop tests** include: CHT (diagonal), SHT (single-forward), THT and, 6-m TH (repeated-forward), and VH **(ci-cv)**. **Other important research measures of functional performance** include: balance, agility or other tasks meaningful to the patient^ **(d)**.	a bi bii ci cii ciii civ cv d

Figure 4 Research recommendations and appropriateness rating. *See online supplemental file 3 for level of supporting evidence, results of expert group appropriateness voting and dissenting viewpoints for all recommendations (and components). ^See supplementary file for examples. Level of appropriateness of the recommendation: appropriateness rating: ✓ = recommendation is appropriate (median scores: ≥7/9), ? = recommendation is uncertain (median scores: 4–6) and X = recommendation is not appropriate (median scores: 1–3). [a]Examples: NICE,[61] American College of Rheumatology,[62] European League against Rheumatism[63] definitions. [b]Domains and instruments are presented in no particular order. Licencing requirements may apply. [c]Provides an overall composite score of knee-related symptoms, function and sports activities. [d]Provides single domain scores for knee-related pain, other symptoms, function in daily living, function in sport and recreation and quality of life, as well as a composite ($KOOS_4$) score of knee-related pain, other symptoms, function in sport and recreation, quality of life. [e]Provides an overall composite score of knee-related physical symptoms, sports/recreation/work/lifestyle, and emotions. [f]The capacity of a muscle to do work (eg, strength, power, endurance). [g]Strength tests should only be performed when safe. Isometric scores are not interchangeable with isokinetic or isotonic scores. As HHD can underestimate strength, it is important to secure the femur, have the patient push into resistance generated by a fixed belt, and for re-assessment to be conducted by the same assessor. 1RM should be based on the average of at least two measures of maximum effort. [h]The action of carrying out or accomplishing a movement, movement task or movement activity. [i]Hop tests should only be performed when safe. Test choice may be influenced by individual presentation, goals, practicality and availability of space. Test is presented in alphabetical order as there is insufficient evidence to inform the 'best' test or 'best' order. ACL anterior cruciate ligament; ACL-QOL, ACL Quality-of-Life Score; ACLR, ACL reconstruction; ACL-RSI, ACL Return to Sport after Injury Scale; BMI, body mass index; EQ-5D, EuroQol 5 Dimensions; GROC, Global Rate of Change; HHD, hand-held dynamometry; IKDC-SKF, International Knee Documentation Committee Subjective Knee Form; KOOS, Knee injury and Osteoarthritis Outcome Score pain, other symptoms, function in sport and recreation (SportRec) and knee-related QOL subscales; K-SES, Knee Self-Efficacy Scale; NICE, National Institute for Health and Care Excellence; NRS, Numerical Rating Scale; pass, Patient acceptable symptom state; PTOA, post-traumatic osteoarthritis; PROs, patient-reported outcomes ; QOL, quality of life; RCT, randomised controlled trial; RM, repetition maximum; SF-12, short form 12; SF-36, short form 36; TSK, Tampa Scale of Kinesiophobia; VAS, Visual Analogue Scale; WOMET, Western Ontario Meniscal Evaluation Tool.

physiotherapy clinicians and non-physiotherapy clinicians were included from the initial priority setting exercise, the evidence synthesis and consensus—however, the dominant perspectives represent clinician scientist physiotherapists. The next steps for the consensus include extensive patient, physiotherapy clinician and non-physiotherapy practitioner consultation through convening and collaborating meetings, and focus groups. It is expected that intent and level of agreement for the recommendations will evolve over time with the engagement of new and diverse perspective, and as new evidence emerges.

CONCLUSION

The OPTIKNEE consensus meetings produced 8 clinical and 6 research recommendations based on a rigorous approach and extensive evidence synthesis. The recommendations can be used to increase awareness about, and advocate for preventing the long-term consequences of traumatic knee injuries. The clinical recommendations can guide rehabilitation practice to improve health outcomes following knee injury. Clinician scientists and researchers can use the definitions and research recommendations to develop, test and implement evidence-based

Box 2 How to apply the OPTIKNEE clinical recommendations

Which patients to discuss and address the risk of knee PTOA with?

⇒ All people with single and multi-structure knee injuries have an elevated risk for PTOA and should be aware of it.

⇒ Those with high risk (ie, intra-articular damage) or symptoms (eg, pain) and/or functional restrictions (eg, less physically active) persisting beyond usual recovery times, or with subsequent knee injury should be taught how to manage this risk.

What can be done to help reduce a patient's risk of knee PTOA and when to do it?

⇒ Collaborate with the patient to meet their informational needs for knee health and OA (education), guide them to self-manage and teach them how to avoid or address risk factors for non-traumatic OA (eg, weight gain, inactivity and thigh muscle weakness) through person-centred goals.

⇒ Start these efforts as close to the time of their knee injury as possible and continue across the lifespan.

What is evidence-based care for ACL tears?

⇒ In most cases, treatment of an ACL tear should start with education and exercise-based rehabilitation (not surgery).

⇒ Ask the patient who they want to work with to make decisions about their knee health and who needs to be 'in the room' for decisions.

⇒ Start a dialogue with the patient (and other stakeholders) about their goals, fears or anxieties, preferences, available resources and go-no-go criteria for non-surgical care, ACLR, supervised rehabilitation, return to activity (training, sport and occupation as appropriate) and ongoing self-management.

⇒ The patient should guide the choice and setting for exercise therapy, but it should include weight-bearing, mobility and open and closed kinetic chain resistance-based neuromuscular control and plyometric exercises that target the leg muscles (specifically, the quadriceps and hamstring) with a dose sufficient to stimulate physiological adaptation.

⇒ To promote the patient's engagement in their exercise program, co-develop short, intermediate and long-term SMART (specific, measurable, attainable, relevant and timebound) goals.

⇒ Guide patients through progressively challenging movement patterns (that are relevant to their lifestyle) to detect motions associated with anxiety or fear, and then encourage them to mindfully explore and expose themselves to that motion or its subcomponents.

What are the most important outcomes to monitor after traumatic knee injury and best options to do it?

⇒ Choose PROs, muscle strength tests and hop tests based on each patient's presentation and goals, and the available resources.

⇒ PROs that assess multiple outcome domains and provide a composite score across various knee injury types may be most practical.

⇒ Some PROs are freely available while other have licencing requirements but could be available through your employer.

Core outcomes to monitor*	Recommended options*
Multiple domain	► KOOS (composite of knee pain, other symptoms, function in sport/recreation and QOL)† ► IKDC (composite of knee symptoms, function and sports activities) ► WOMET (composite of knee physical symptoms, sports/recreation/work/lifestyle and emotions)‡
Knee pain	► KOOS pain subscale† ► VAS or NRS
Other knee symptoms§	► KOOS symptoms subscale†
Knee-related adverse events§	► Number of ipsilateral and contralateral knee injuries, including graft tears ► Number of locking or giving away episodes
Knee-related cognitive behavioural factors§	► TSK-11 (fear or anxiety of motion) ► K-SES (knee self-efficacy) ► ACL-RSI (knee confidence and psychological readiness)¶
Self-reported physical function	► KOOS function in daily living subscale† ► KOOS function in sport and recreation subscale†
Muscle function**	► Peak knee extensor/flexor strength with computerised dynamometry (concentric isokinetic ≥60°/s) ► Peak knee extensor/flexor strength with HHD (isometric maximum effort)§ ► Peak knee extensor/flexor strength with weight machine (concentric 1RM)††
Functional performance‡‡	► One or a combination of the SHT, THT, 6 m THT, CHT or VHT ► A battery of forward (SHT, THT and 6 m THT), diagonal (CHT) and vertical (VHT) hop tests§§
Knee-related QOL	► KOOS QOL subscale† ► ACL QOL¶
Physical activity and sport participation§	► Step count ► Minutes of moderate to vigorous physical activity ► Questions about sport resumption, frequency

⇒ Other outcomes that might be important to consider are body weight, health-related QOL, the patient's occupation, care-giving and community roles and injury-related mental health such as depression and anxiety.

⇒ Only refer the patient for diagnostic imaging if you need the results to direct treatment.

Continued

Box 2 Continued

How and when should monitoring important outcomes be done after a traumatic knee injury?

⇒ Consider assessing at least 1 multidomain PRO, 1 knee extensor and flexor strength test, and 1 hop test at a patients' first and last treatment session, and every 4–6 weeks in between (as applicable).

⇒ Consider asking patients to complete PROs in the waiting room before their treatment session.

What is the best way to interpret and record the current state and change of important outcomes?

⇒ Ask the patient if they feel their current state is acceptable/satisfactory and if they have noticed a meaningful change in the outcome.

⇒ Consider asking the patient about responses to individual PROs items to understand their experience.

⇒ Record the baseline and follow-up score, change in direction (improvement or deterioration) in the outcome, if the patient felt the change was meaningful and if they feel that their current state of that outcome is acceptable/satisfactory§.

*Outcomes and measures are presented in no particular order.
†Freely available at www.koos.nu.
‡For use after meniscal injuries only.
§See online supplemental file 4 for further examples.
¶For use after ACL tear injuries only.
**The capacity of a muscle to do work (eg, strength, power and endurance).
††Strength tests should only be performed when it is safe. Isometric scores are not interchangeable with isokinetic or isotonic scores. As HHD can underestimate strength, it is important to secure the femur, have the patient push into resistance generated by a fixed belt (not the assessor hand) and for re-assessment to be conducted by the same assessor. 1RM should be based on the average of at least two repeated measures of maximum effort.
‡‡The action of carrying out or accomplishing a movement, movement task or movement activity.
§§Hop tests should only be performed when it is safe.
6 m THT, 6-metre Timed Hop Test; ACL, anterior cruciate ligament, ACL-QOL, ACL Quality-of-Life Score; ACLR,ACL reconstruction; ACL-RSI, ACL Return to Sport after Injury Scale; CHT, Crossover Hop Test; HHD, Hand-held dynamometry; IKDC-SKF, International Knee Documentation Committee Subjective Knee Form; K-SES, Knee Self-Efficacy Scale; KOOS, Knee injury and Osteoarthritis Outcome Score; NRS, Numerical Rating Scale; PTOA, post-traumatic osteoarthritis; PROs, patient-reported outcomes ; QOL, quality of life; RM, repetition maximum; SHT, Single Hop Test; THT, Triple Hop Test; TSK, Tampa Scale of Kinesiophobia; VAS, Visual Analogue Scale; VHT, Vertical Hop Test; WOMET, Western Ontario Meniscal Evaluation Tool.

rehabilitation programmes, and facilitate data synthesis to reduce the burden of OA.

Author affiliations
[1]Department of Physical Therapy, The University of British Columbia, Vancouver, British Columbia, Canada
[2]Arthritis Research Canada, Vancouver, British Columbia, Canada
[3]Sport Injury Prevention Research Centre, Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada
[4]La Trobe Sport and Exercise Medicine Research Centre, School of Allied Health, Human Services and Sport, La Trobe University, Melbourne, Victoria, Australia
[5]Department of Physiotherapy and Occupational Therapy, Copenhagen University Hospital, Kobenhavn, Denmark
[6]Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark
[7]Division of Orthopaedic Surgery, Oslo University Hospital, Oslo, Norway
[8]Department of Interdisciplinary Health Sciences, Faculty of Medicine, University of Oslo, Oslo, Norway
[9]The Research Unit PROgrez, Department of Physiotherapy and Occupational Therapy, Næstved-Slagelse-Ringsted Hospitals, Slagelse, Region Zealand, Denmark
[10]Centre for Health Exercise and Sports Medicine, Department of Physiotherapy, University of Melbourne, Melbourne, Victoria, Australia
[11]Department of Family Practice, The University of British Columbia, Vancouver, British Columbia, Canada
[12]Department of General Practice, Erasmus MC Medical University Center, Rotterdam, The Netherlands
[13]Department of Orthopaedics and Sports Medicine, Erasmus MC Medical University Center, Rotterdam, The Netherlands
[14]Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, Norway
[15]Department of Orthopaedic Surgery, Wake Forest School of Medicine, Winston-Salem, North Carolina, USA
[16]North Queensland Physiotherapy Centre, Townsville, Queensland, Australia
[17]Department of Orthopaedic Surgery, Copenhagen University Hospital Hvidovre, Copenhagen, Denmark
[18]School of Kinesiology, University of British Columbia, Vancouver, British Columbia, Canada
[19]Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Alberta, Canada
[20]Research Unit for General Practice, Department of Public Health, University of Southern Denmark, Odense, Denmark
[21]Department of Rehabilitation Science and Health Technology, Oslo Metropolitan University, Oslo, Norway
[22]Department of Physical Therapy Education, College of Health Sciences, Western University of Health Sciences, Lebanon, Oregon, USA
[23]School of Allied Health, University of Limerick, Limerick, Ireland
[24]Department of Orthopaedic Surgery, Erasmus MC Medical University Center, Rotterdam, Netherlands
[25]Schroeder Arthritis Institute, Krembil Research Institute, University Health Network, Toronto, Ontario, Canada
[26]Faculty of Medicine, Department of Clinical Sciences Lund, Orthopaedics, Lunds Universitet, Lund, Sweden
[27]Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
[28]McCaig Institute for Bone and Joint Health, University of Calgary, Calgary, Alberta, Canada

Twitter Jackie L Whittaker @jwhittak_physio, Adam G Culvenor @agculvenor, Carsten Bogh Juhl @BoghJuhl, Bjørnar Berg @berg_bjornar, Alessio Bricca @a_bricca, Stephanie Rose Filbay @stephfilbay, Pætur Holm @PM_Holm, Erin Macri @Erin_Macri, Anouk P Urhausen @AnoukUrhausen, Clare L Ardern @clare_ardern, Andrea M Bruder @AndreaBruder, Garrett S Bullock @DRGSBullock, Allison M Ezzat @AllisonEzzat, Michael Girdwood @m_girdwood, Melissa Haberfield @melhabphysio, Mick Hughes @mickwhughes, Lina Holm Ingelsrud @LIngelsrud, Karim M Khan @KarimKhan_IMHA, Christina Y Le @yegphysio, Justin M Losciale @JayLos18, Matilde Lundberg @LundbergMatilde, Maxi Miciak @MaxiMiciak, Britt Elin Øiestad @Britt_Elin, Brooke Patterson @Knee_Howells, Anu M Räisänen @amraisanen, Søren T Skou @STSkou, Jonas Bloch Thorlund @jbthorlund, Clodagh Toomey @clo2me, Linda K Truong @LKTphysio, Thomas James West @tsewmot, James Justin Young @James_J_Young, Carolyn Emery @CarolynAEmery, Marienke van Middelkoop @mvanmiddelkoop, Ewa M Roos @ewa_roos and Kay M Crossley @kaymcrossley

Acknowledgements The authors would like to express our deepest thanks to Alison Hoens who is the knowledge broker for the OPTIKNEE consensus.

Contributors AGC, ARF, CE, EM, EMR, KMC, STS, JBT and JLW participated in the OPTIKNEE planning meetings (2017–2019). JLW, ER and KMC hosted the 2019 priority setting meeting. JLW, AGC, AME, AMR, BP, CE, CT, CYL, EM, EMR, JBT, KMC, LKT, LSL, MAR, MM, MVM, SRF and STS participated in the priority setting meeting. JLW, KMC, AGC and ER were involved in the design of the consensus. JLW coordinated the consensus. JLW, AGC, BB, AB, SRF, PH, EM, APU, CE, MAR, MvM, EMR and KMC led or were senior authors of individuals systematic reviews. CBJ provided methodological support related to evidence synthesis and meta-analyses.

JLW, AGC, BB, SRF, PH, EM, APU, BEØ, MAR, MvM, EMR and KMC met every 4–6 weeks over the systematic review protocol development and conduct stage. All authors participated in the consensus meetings. JLW wrote the first draft of the manuscript. All authors contributed to reviewing, editing and revising the manuscript and approved the final submitted version. JLW is the guarantor.

Funding JLW is supported by a Michael Smith Foundation for Health Research a Scholar Award (SCH-2020-0403) and an Arthritis Society STAR Career Development Award (STAR-19-0493). STS is supported by a program grant from Region Zealand (Exercise First) and two grants from the European Union's Horizon 2020 research and innovation program, one from the European Research Council (MOBILIZE, grant agreement No 801790) and the other under grant agreement No 945377 (ESCAPE). CAE holds a Tier 1 Canada Research Chair. JLM is supported by the Arthritis Society. LKT is supported by a Canadian Institutes of Health Research Fellowship. AGC is supported by a National Health and Medical Research Council (NHMRC) of Australia Investigator Grant (GNT2008523). MG is supported by a NHMRC Post Graduate Scholarship (GNT1190882). EM was supported by a CIHR Banting Postdoctoral Fellowship. PH is supported by a program grant from Region Zealand (Exercise First). AB is supported by a program grant from the European Research Council (MOBILIZE, grant agreement No 801790). APU and MAR are supported by research funding from the National Institutes of Health, USA, Grant (R37HD37985). AME is supported by a CIHR Postdoctoral Fellowship. CMT is supported by a Health Research Board Emerging Investigator Award (EIA-2019-008). The authors would like to acknowledge librarian scientist Wichor M Bramer, PhD (Erasmus MC), who performed the database searches, librarian scientist Charlotte Beck (UBC) who assisted in translating the MEDLINE search strategy into SPORTDiscus and other authors of the OPTIKNEE reviews that did not take part in the OPTIKNEE consensus meetings: Berend Terluin, Staffan Larsson and André Struglics. The authors would like to express our deepest thanks to Alison Hoens who is the knowledge broker for the OPTIKNEE consensus. Initial priority theme setting for the OPTIKNEE consensus (https://bit.ly/OPTIKNEE) was supported by a Canadian Institutes of Health Research Planning and Dissemination Grant (principal investigator JLW #161821).

Competing interests JLW, AGC, BP, EM and CE are associate editors of the *British Journal of Sports Medicine* (BJSM). CLA is the editor in chief and JLW an editor with the *Journal of Orthopaedic and Sports Physical Therapy* (JOSPT). AGC is an associate editor of *Osteoarthritis and Cartilage*. SF is an associate editor for *Journal of Science in Medicine and Sport*. JBT holds a research grant from Pfizer outside the submitted work. STS is co-founders of Good Life with Osteoarthritis from Denmark (GLA:D), associate editor of the JOSPT and has received grants from the Lundbeck Foundation and personal fees from Munksgaard and TrustMe-Ed, outside the submitted work. CMT is project leader of GLA:D, Ireland. MAR is a project leader of the Active Living with Osteoarthritis in Norway (AktivA), a not-for-profit initiative to implement clinical guidelines in primary health care in Norway. ER is a deputy editor of *Osteoarthritis and Cartilage*, developer of Knee injury and Osteoarthritis Outcome Score and several other freely available patient-reported outcomes, and founder of GLA:D. KMC is a senior advisor of BJSM, project leader of the GLA:D, Australia, and holds a research grant from Levin Health outside the submitted work.

Patient and public involvement statement One individual with lived experience of ACL tear (and ACL reconstruction; ACLR) and four clinicians (i.e., physiotherapists, orthopaedic surgeons) contributed to the priority theme setting for the OPTIKNEE consensus. One patient partner and one clinician (sports and exercise medicine physician) were authors on the risk factor review, and one additional patient and clinician partner provided feedback on one of the intervention reviews30. A patient partner, and a clinician (physiotherapist) provided feedback on this manuscript.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

ORCID iDs
Jackie L Whittaker http://orcid.org/0000-0002-6591-4976
Adam G Culvenor http://orcid.org/0000-0001-9491-0264
Bjørnar Berg http://orcid.org/0000-0002-9017-5562
Alessio Bricca http://orcid.org/0000-0001-9717-918X
Stephanie Rose Filbay http://orcid.org/0000-0002-9624-0791
Anouk P Urhausen http://orcid.org/0000-0002-4409-1501
Andrea M Bruder http://orcid.org/0000-0001-5422-5756
Garrett S Bullock http://orcid.org/0000-0003-0236-9015
Allison M Ezzat http://orcid.org/0000-0003-2576-0412
Michael Girdwood http://orcid.org/0000-0001-6477-7263
Melissa Haberfield http://orcid.org/0000-0002-6366-0896
Lina Holm Ingelsrud http://orcid.org/0000-0003-2261-7709
Karim M Khan http://orcid.org/0000-0002-9976-0258
Christina Y Le http://orcid.org/0000-0003-0241-5157
Justin M Losciale http://orcid.org/0000-0001-5135-1191
Maxi Miciak http://orcid.org/0000-0003-4686-9206
Britt Elin Øiestad http://orcid.org/0000-0002-0547-9781
Brooke Patterson http://orcid.org/0000-0002-6570-5429
Anu M Räisänen http://orcid.org/0000-0003-3056-8169
Søren T Skou http://orcid.org/0000-0003-4336-7059
Jonas Bloch Thorlund http://orcid.org/0000-0001-7789-8224
Linda K Truong http://orcid.org/0000-0002-0728-6297
Belle L. van Meer http://orcid.org/0000-0002-3413-7510
Thomas James West http://orcid.org/0000-0002-6297-1094
James Justin Young http://orcid.org/0000-0003-1210-3106
L Stefan Lohmander http://orcid.org/0000-0002-5424-9448
Carolyn Emery http://orcid.org/0000-0002-9499-6691
Marienke van Middelkoop http://orcid.org/0000-0001-6926-0618
Ewa M Roos http://orcid.org/0000-0001-5425-2199
Kay M Crossley http://orcid.org/0000-0001-5892-129X

REFERENCES

1 Peat G, Bergknut C, Frobell R, *et al*. Population-Wide incidence estimates for soft tissue knee injuries presenting to healthcare in southern Sweden: data from the Skåne healthcare register. *Arthritis Res Ther* 2014;16:R162.
2 Alexandrescu R, O'Brien SJ, Lecky FE. A review of injury epidemiology in the UK and Europe: some methodological considerations in constructing rates. *BMC Public Health* 2009;9:226.
3 Louw QA, Manilall J, Grimmer KA. Epidemiology of knee injuries among adolescents: a systematic review. *Br J Sports Med* 2008;42:2–10.
4 Gianotti SM, Marshall SW, Hume PA, *et al*. Incidence of anterior cruciate ligament injury and other knee ligament injuries: a national population-based study. *J Sci Med Sport* 2009;12:622–7.
5 Gage BE, McIlvain NM, Collins CL, *et al*. Epidemiology of 6.6 million knee injuries presenting to United States emergency departments from 1999 through 2008. *Acad Emerg Med* 2012;19:378–85.
6 Podlog L, Wadey R, Stark A, *et al*. An adolescent perspective on injury recovery and the return to sport. *Psychol Sport Exerc* 2013;14:437–46.
7 Ardern CL, Taylor NF, Feller JA, *et al*. Fifty-five per cent return to competitive sport following anterior cruciate ligament reconstruction surgery: an updated systematic review and meta-analysis including aspects of physical functioning and contextual factors. *Br J Sports Med* 2014;48:1543–52.
8 Bell DR, Pfeiffer KA, Cadmus-Bertram LA, *et al*. Objectively measured physical activity in patients after anterior cruciate ligament reconstruction. *Am J Sports Med* 2017;45:1893–900.
9 Toomey CM, Whittaker JL, Doyle-Baker PK, *et al*. Does a history of youth sport-related knee injury still impact accelerometer-measured levels of physical activity after 3-12 years? *Phys Ther Sport* 2022;55:90–7.
10 Toomey CM, Whittaker JL, Nettel-Aguirre A, *et al*. Higher fat mass is associated with a history of knee injury in youth sport. *J Orthop Sports Phys Ther* 2017;47:80–7.
11 Filbay SR, Culvenor AG, Ackerman IN, *et al*. Quality of life in anterior cruciate ligament-deficient individuals: a systematic review and meta-analysis. *Br J Sports Med* 2015;49:1033–41.
12 Filbay SR, Ackerman IN, Dhupelia S, *et al*. Quality of life in symptomatic individuals after anterior cruciate ligament reconstruction, with and without radiographic knee osteoarthritis. *J Orthop Sports Phys Ther* 2018;48:398–408.
13 Suter LG, Smith SR, Katz JN, *et al*. Projecting lifetime risk of symptomatic knee osteoarthritis and total knee replacement in individuals sustaining a complete anterior cruciate ligament tear in early adulthood. *Arthritis Care Res* 2017;69:201–8.
14 Snoeker B, Turkiewicz A, Magnusson K, *et al*. Risk of knee osteoarthritis after different types of knee injuries in young adults: a population-based cohort study. *Br J Sports Med* 2020;54:725–30.
15 Fernandes GS, Parekh SM, Moses J, *et al*. Prevalence of knee pain, radiographic osteoarthritis and arthroplasty in retired professional footballers compared with men in the general population: a cross-sectional study. *Br J Sports Med* 2018;52:678–83.
16 Poulsen E, Goncalves GH, Bricca A, *et al*. Knee osteoarthritis risk is increased 4-6 fold after knee injury - a systematic review and meta-analysis. *Br J Sports Med* 2019;53:1454–63.
17 Filbay SR, Skou ST, Bullock GS, *et al*. Long-Term quality of life, work limitation, physical activity, economic cost and disease burden following ACL and meniscal injury: a systematic review and meta-analysis for the OPTIKNEE consensus. *Br J Sports Med* 2022;56:1465–74.
18 Riley RD, Hayden JA, Steyerberg EW, *et al*. Prognosis research strategy (progress) 2: prognostic factor research. *PLoS Med* 2013;10:e1001380.

19 Lau BHF, Lafave MR, Mohtadi NG, *et al*. Utilization and cost of a new model of care for managing acute knee injuries: the Calgary acute knee injury clinic. *BMC Health Serv Res* 2012;12:445.
20 Feucht MJ, Cotic M, Saier T, *et al*. Patient expectations of primary and revision anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2016;24:201–7.
21 Marshall DA, Currie GR, Whittaker JL, *et al*. Matched comparison of health care use and costs 3-10 years after a youth sport-related knee injury. *Osteoarthritis Cartilage* 2019;27:S296–7.
22 Truong LK, Mosewich AD, Miciak M, *et al*. Balance, reframe, and overcome: the attitudes, priorities, and perceptions of exercise-based activities in youth 12-24 months after a sport-related ACL injury. *J Orthop Res* 2022;40:170–81.
23 Watt FE, Corp N, Kingsbury SR, *et al*. Towards prevention of post-traumatic osteoarthritis: report from an international expert Working group on considerations for the design and conduct of interventional studies following acute knee injury. *Osteoarthritis Cartilage* 2019;27:23–33.
24 Whittaker JL, Roos EM. A pragmatic approach to prevent post-traumatic osteoarthritis after sport or exercise-related joint injury. *Best Pract Res Clin Rheumatol* 2019;33:158-171.
25 Fitch K, Bernstein S, Aguilar MD, *et al*. *The RAND/UCLA Appropriateness Method User's Manual*. Santa Monica, CA, USA: RAND Corporation, 2001.
26 Manera K, Hanson CS, Gutman T, *et al*. *Consensus methods: nominal group technique in Handbook of research methods in health social sciences*. Singapore: Springer nature, 2019.
27 Brouwers MC, Kho ME, Browman GP, *et al*. Agree II: advancing Guideline development, reporting and evaluation in health care. *CMAJ* 2010;182:E839–42.
28 Jünger S, Payne SA, Brine J, *et al*. Guidance on conducting and reporting Delphi studies (CREDES) in palliative care: recommendations based on a methodological systematic review. *Palliat Med* 2017;31:684–706.
29 Whittaker JL, Losciale JM, Juhl CB, *et al*. Risk factors for knee osteoarthritis after traumatic knee injury: a systematic review and meta-analysis of randomised controlled trials and cohort studies for the OPTIKNEE consensus. *Br J Sports Med* 2022;56:1406–21.
30 Culvenor AG, Girdwood MA, Juhl CB, *et al*. Rehabilitation after anterior cruciate ligament and meniscal injuries: a best-evidence synthesis of systematic reviews for the OPTIKNEE consensus. *Br J Sports Med* 2022;56:1445–53.
31 Li S-A, Yousefi-Nooraie R, Guyatt G, *et al*. A few panel members dominated Guideline development meeting discussions: social network analysis. *J Clin Epidemiol* 2022;141:1–10.
32 Nair R, Aggarwal R, Khanna D. Methods of formal consensus in classification/diagnostic criteria and Guideline development. *Semin Arthritis Rheum* 2011;41:95–105.
33 Shrier I. Consensus statements that fail to recognise dissent are flawed by design: a narrative review with 10 suggested improvements. *Br J Sports Med* 2021;55:545–9.
34 Dobbins M, Robeson P, Ciliska D, *et al*. A description of a knowledge broker role implemented as part of a randomized controlled trial evaluating three knowledge translation strategies. *Implement Sci* 2009;4:23.
35 Holm PM, Juhl C, Culvenor AG. The effects of different management strategies or rehabilitation approaches on knee joint structural and molecular biomarkers following knee injury: a systematic review of ransomised controlled trials for the OPTIKNEE consensus. Under Review.
36 Macri EM, Young JJ, Ingelsrud LH, *et al*. Meaningful thresholds for patient-reported outcomes following interventions for anterior cruciate ligament tear or traumatic meniscus injury: a systematic review for the OPTIKNEE consensus. *Br J Sports Med* 2022;56:1432–44.
37 Urhausen AP, Berg B, Øiestad BE, *et al*. Measurement properties for muscle strength tests following anterior cruciate ligament and/or meniscus injury: what tests to use and where do we need to go? A systematic review with meta-analyses for the OPTIKNEE consensus. *Br J Sports Med* 2022;56:1422–31.
38 Berg B, Urhausen AP, Oiestad BE, *et al*. What tests should be used to assess functional performance in youth and young adults following anterior cruciate ligament or meniscal injury? A systematic review of measurement properties for the OPTIKNEE consensus. *Br J Sports Med* 2022;56:1454–64.
39 Guyatt GH, Oxman AD, Vist GE, *et al*. Grade: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;336:924–6.
40 Schünemann HJ, Best D, Vist G, *et al*. Letters, numbers, symbols and words: how to communicate grades of evidence and recommendations. *CMAJ* 2003;169:677–80.
41 Michie S, Richardson M, Johnston M, *et al*. The behavior change technique taxonomy (V1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann Behav Med* 2013;46:81–95.
42 Meade LB, Bearne LM, Sweeney LH, *et al*. Behaviour change techniques associated with adherence to prescribed exercise in patients with persistent musculoskeletal pain: systematic review. *Br J Health Psychol* 2019;24:10–30.
43 Whittaker JL, Truong LK, Losciale JM, *et al*. Efficacy of the SOAR knee health program: protocol for a two-arm stepped-wedge randomized delayed-controlled trial. *BMC Musculoskelet Disord* 2022;23:85.
44 Frobell RB, Roos EM, Roos HP, *et al*. A randomized trial of treatment for acute anterior cruciate ligament tears. *N Engl J Med* 2010;363:331–42.
45 Skou ST, Hölmich P, Lind M, *et al*. Early surgery or exercise and education for meniscal tears in young adults. *NEJM Evid* 2022;1:EVIDoa2100038.
46 Blazey P, Crossley KM, Ardern CL, *et al*. It is time for consensus on 'consensus statements'. *Br J Sports Med* 2022;56:306–7.
47 Slade SC, Dionne CE, Underwood M, *et al*. Consensus on exercise reporting template (CERT): explanation and elaboration statement. *Br J Sports Med* 2016;50:1428–37.
48 Mokkink LB, de Vet HCW, Prinsen CAC, *et al*. COSMIN risk of bias checklist for systematic reviews of patient-reported outcome measures. *Qual Life Res* 2018;27:1171–9.
49 Fink A, Kosecoff J, Chassin M, *et al*. Consensus methods: characteristics and guidelines for use. *Am J Public Health* 1984;74:979–83.
50 Schunemann HJ, Brozek J, Guyatt G. *GRADE Handbook for grading quality of evidence and strength of recommendatoins*. The GRADE Working Group, 2013.
51 Hayden JA, van der Windt DA, Cartwright JL, *et al*. Assessing bias in studies of prognostic factors. *Ann Intern Med* 2013;158:280–6.
52 Huguet A, Hayden JA, Stinson J, *et al*. Judging the quality of evidence in reviews of prognostic factor research: adapting the grade framework. *Syst Rev* 2013;2:71.
53 Whiting P, Savović J, Higgins JPT, *et al*. ROBIS: a new tool to assess risk of bias in systematic reviews was developed. *J Clin Epidemiol* 2016;69:225–34.
54 Pollock A, Farmer SE, Brady MC, *et al*. An algorithm was developed to assign grade levels of evidence to comparisons within systematic reviews. *J Clin Epidemiol* 2016;70:106–10.
55 Devji T, Carrasco-Labra A, Qasim A, *et al*. Evaluating the credibility of anchor based estimates of minimal important differences for patient reported outcomes: instrument development and reliability study. *BMJ* 2020;369:m1714.
56 Mokkink LB, Terwee CB, Patrick DL, *et al*. The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. *Qual Life Res* 2010;19:539–49.
57 Prinsen CAC, Mokkink LB, Bouter LM, *et al*. COSMIN guideline for systematic reviews of patient-reported outcome measures. *Qual Life Res* 2018;27:1147–57.
58 Mokkink LB, Boers M, van der Vleuten CPM, *et al*. COSMIN risk of bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments: a Delphi study. *BMC Med Res Methodol* 2020;20:293.
59 Whittaker JL, Runhaar J, Bierma-Zeinstra S, *et al*. A lifespan approach to osteoarthritis prevention. *Osteoarthritis Cartilage* 2021;29:1638–53.
60 Boyd KM. Disease, illness, sickness, health, healing and wholeness: exploring some elusive concepts. *Med Humanit* 2000;26:9–17.
61 National Institute of Health Care Excellence. Osteoarthritis: care and management in adults. 2014, 2014. Available: https://ard.bmj.com/content/69/3/483
62 Altman R, Asch E, Bloch D, *et al*. Development of criteria for the classification and reporting of osteoarthritis. classification of osteoarthritis of the knee. diagnostic and therapeutic criteria Committee of the American rheumatism association. *Arthritis Rheum* 1986;29:1039–49.
63 Zhang W, Doherty M, Peat G, *et al*. EULAR evidence-based recommendations for the diagnosis of knee osteoarthritis. *Ann Rheum Dis* 2010;69:483–9.

SUPPLEMENTARY FILE 1: Consensus Meetings Materials

1. **Consensus meetings agendas**
2. **Draft Definitions Discussed at Consensus Meeting 1**
3. **Draft Recommendations (clinical and research) Discussed at Consensus Meetings 2-6**
4. **Evidence Summary for Review Prior to Consensus Meetings 2-6**

Whittaker JL, *et al. Br J Sports Med* 2022;0:1–13. doi: 10.1136/bjsports-2022-106299

1. CONSENSUS MEETINGS AGENDAS

DATES: Six, 2-hour sessions between January 31-May 2, 2022. This will allow us to submit the consensus document by July 2022

LOCATION: https://ubc.zoom.us Meeting ID: XXX XXXX XXXX, Passcode: XXXXXX

ATTENDEE LIST: Clare Ardern, Bjørnar Berg, Alessio Bricca, Andrea Bruder, Garrett Bullock, Kay Crossley, Adam Culvenor, Carolyn Emery, Allison Ezzat, Stephanie Filbay, Mick Girdwood, Mel Haberfield, Paetur Holm, Lina Holm Ingelsrud, Carsten Juhl, Karim Khan, Chris Le, Stefan Lohmander, Justin Losciale, Matilde Lundberg, Erin Macri, Britt Elin Øiestad, Brooke Patterson, Anu Raisanen, May Arna Risberg, Ewa Roos, Soren Skou, Jonas Thorlund, Clodagh Toomey, Linda Truong, Anouk Urhausen, Belle van Meer, Marienke van Middelkoop, Tom West, Jackie Whittaker, James Young,

MEETING 1: Monday January 31, 2022 at 11:00-13:00 PST (12:00-14:00 MST, 15:00-17:00 GMT, 20:00-22:00 CET, and +1 6:00-8:00 AEDT) OPTIKNEE OVERVIEW & DEFINITIONS			
Time	**Agenda Item**	**Facilitator/Presenter**	**Attachment(s)**
00-0:20	Welcome & Introductions Purpose of the OPTIKNEE Consensus and Guiding Principles Summary of Work Completed & Next Steps	*Jackie Whittaker & Steering Committee*	*1 - Proposed OPTIKNEE 2022 Schedule* *2 - Evidence Summaries*
0:20-0:30	Definitions & Overarching Concepts: Summary • *3 – Abbreviations & Definitions*	*Adam Culvenor*	*3 - Abbreviations & Definitions*
0:30-1:00	Small group (breakout rooms of ~n=6) discussion of Abbreviations & Definitions • *(see below for assignments)*	*Group Facilitators*	
1:00-1:30	Small group discussion summaries by group facilitators (*5 min each)**	*Group Facilitators*	
1:30-2:00	Full group discussion of Abbreviations & Definitions**	*Facilitator Clare Ardern*	

**Summarize agreement, dissent, and wording changes discussed during small group conversations. **Attempt to reach a general consensus/understanding of abbreviations, definitions and overarching concepts. ***Delegates will indicate their level of agreement and record any dissenting viewpoint.*

Group Number	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Facilitator	*Khan*	*Ardern*	*Macri*	*Lohmander*	*Emery*
Trainee Expert	*West**	*Truong**	*Patterson**	*Le**	*Losciale**
Group Members	*Filbay*	*Holm*	*Berg*	*Urhausen*	*van Middelkoop*
	Øiestad	*Risberg*	*Skou*	*Toomey*	*Bricca*
	Raisanen	*Bruder*	*Ezzat*	*Girdwood*	*vanMeer*
	Thorlund	*Young*	*Haberfield*	*Bullock*	*Lundberg*
		Ingelsrud			

**Responsible for recording breakout rooms, keeping an eye on the chat box, saving the chat box conversation, reaching out to steering committee if questions arise, keeping an eye on the clock. Group facilitator, trainee exerts and grouping varied from meeting to meeting.*

MEETING 2: 11:00 am PST, February 21, 2022 (see here for local time) - RISK FACTORS FOR KNEE PTOA			
Time	**Agenda Item**	**Facilitator/Presenter**	**Attachment(s)**
0:00-0:15	Who and What to Target, and When to Act, to Reduce the Risk of Knee PTOA: Summary and Recommendations • *4 - Clinical Recommendations C1a-c, C2a-b* • *4 - Research Recommendations R1a-c, R2a-b*	*Jackie Whittaker*	*2 - Evidence Summaries* *3 - Abbreviations & Definitions* *4 - Recommendations* *5 - Risk Factor SR*
0:15-0:45	Small group (breakout rooms of ~n=6) discussion of recommendations • *(see below for assignments)*	*Group Facilitators*	
0:45-1:15	Small group discussion summaries by group facilitators (*5 min each)**	*Group Facilitators*	
1:15-1:55	Full group discussion of Recommendations *C1a-c, C2a-b, R1c, R2a-b* **	*Facilitator Clare Ardern*	
1:55-2:00	Summary	*Adam Culvenor*	
2:00-2:15	Vote on agreement for definitions (D1-7) through an anonymous URL***	*Online Voting*	

**Summarize agreement, dissent, and wording changes discussed during small group conversations. **Attempt to reach a general consensus/understanding of abbreviations, definitions and overarching concepts. ***Delegates will indicate their level of agreement and record any dissenting viewpoint.*

MEETING 3: 12:00 pm PST, March 14, 2022 (see here for local time) - ACL TEAR REHABILITATION APPROACH & INTERVENTIONS			
Time	**Agenda Item**	**Facilitator/Presenter**	**Attachment(s)**
0:00-0:15	What to Do After an ACL Tear and When: Summary and Recommendations • *4 - Clinical Recommendations C3a-f, C4a, C5a* • *4 - Research Recommendations R2c*	*Adam Culvenor* *Paetur Holm*	*2 - Evidence Summaries* *3 - Abbreviations & Definitions* *4 - Recommendations* *6, 7 - Intervention SRs*
0:15-0:45	Small group (breakout rooms of ~n=6) discussion of recommendations • *(see below for assignments)*	*Group Facilitators*	
0:45-1:15	Small group discussion summaries by group facilitators (*5 min each)**	*Group Facilitators*	
1:15-1:55	Full group discussion of Recommendations *C3a-f, C4a, C5a, R2c*	*Facilitator Clare Ardern*	
1:55-2:00	Summary	*Jackie Whittaker*	
2:00-2:15	Vote on agreement for recommendations (*C1a-c, C2a-b & R1a-c, R2a-b*) through an anonymous URL***	*Online Voting*	

**Summarize agreement, dissent, and wording changes discussed during small group conversations. **Attempt to reach a general consensus/understanding of abbreviations, definitions and overarching concepts. ***Delegates will indicate their level of agreement and record any dissenting viewpoint*

MEETING 4: 12:00 pm PST, March 28, 2022 (see here for local time) – BURDEN OF KNEE INJURY (ACL TEAR)			
Time	**Agenda Item**	**Facilitator/Presenter**	**Attachment(s)**
0:00-0:15	What to Monitor and When: Summary and Recommendations • *4 - Clinical Recommendations C5a-c* • *4 - Research Recommendations R3a-d*	*Stephanie Filbay*	*2 - Evidence Summaries* *3 - Abbreviations & Definitions* *4 - Recommendations* *8 - Burden SR*
0:15-0:45	Small group (breakout rooms of ~n=6) discussion of recommendations • *(see below for assignments)*	*Group Facilitators*	
0:45-1:15	Small group discussion summaries by group facilitators (*5 min each)**	*Group Facilitators*	
1:15-1:55	Full group discussion of Recommendations *C5a-c, R3a-d*	*Facilitator Clare Ardern*	
1:55-2:00	Summary	*Adam Culvenor*	
2:00-2:15	Vote on agreement for recommendations (*C3a-f, C4a, C5a, R2c*) through an anonymous URL***	*Online Voting*	

**Summarize agreement, dissent, and wording changes discussed during small group conversations. **Attempt to reach a general consensus/understanding of abbreviations, definitions and overarching concepts. ***Delegates will indicate their level of agreement and record any dissenting viewpoint*

MEETING 5: 12:00 pm, April 19, 2022 (see here for local time) - PROMs			
Time	**Agenda Item**	**Facilitator/Presenter**	**Attachment(s)**
0:00-0:15	PROM Selection and Interpretation: Summary and Recommendations • *4 - Clinical Recommendations C6a, C7a-e* • *4 - Recommendations Research R4a-c*	*Erin Macri*	*2 - Evidence Summaries* *3 - Abbreviations & Definitions* *4 - Recommendations* *9 - PROMs SR*
0:15-0:45	Small group (breakout rooms of ~n=6) discussion of recommendations • *(see below for assignments)*	*Group Facilitators*	
0:45-1:15	Small group discussion summaries by group facilitators (*5 min each)**	*Group Facilitators*	
1:15-1:55	Full group discussion of Recommendations *C6a, C7a-e, R4a-c*	*Facilitator Clare Ardern*	
1:55-2:00	Summary	*Adam Culvenor*	
2:00-2:15	Vote on agreement for recommendations (*C5a-c, R3a-d*) through an anonymous URL***	*Online Voting*	

**Summarize agreement, dissent, and wording changes discussed during small group conversations. **Attempt to reach a general consensus/understanding of abbreviations, definitions and overarching concepts. ***Delegates will indicate their level of agreement and record any dissenting viewpoint*

MEETING 6: 4:00 am PST, May 2, 2022 (see here for local time) – MUSCLE STRENGTH & FUNCITONAL PERFORMANCE			
Time	**Agenda Item**	**Facilitator/Presenter**	**Attachment(s)**
0:00-0:15	Muscle Function & Functional Performance: Summary & Recommendations • *4 - Clinical Recommendations C6c-g, C7a,b,d* • *5 - Research Recommendations R5a-c, R6a-d*	*Anouk Urhausen* *Bjørnar Berg*	*2 - Evidence Summaries* *3 - Abbreviations & Definitions* *4 - Recommendations* *10,11 - Muscle Strength and Functional Performance evidence summaries and SRs*
0:15-0:45	Small group (breakout rooms of ~n=6) discussion of recommendations • *(see below for assignments)*	*Group Facilitators*	
0:45-1:15	Small group discussion summaries by group facilitators (*5 min each)**	*Group Facilitators*	
1:15-1:55	Full group discussion of Recommendations *C6c-g, C7a,b,d, R5a-c, R6a-d*	*Facilitator Clare Ardern*	
1:55-2:00	Summary	*Jackie Whittaker*	
2:00-2:15	Vote on agreement for recommendations (*C5a-c, R3a-d*) through an online anonymous link***	*Online Voting*	

**Summarize agreement, dissent, and wording changes discussed during small group conversations. **Attempt to reach a general consensus/understanding of abbreviations, definitions and overarching concepts. ***Delegates will indicate their level of agreement and record any dissenting viewpoint*

2. Draft Definitions for Consensus Meeting 1

Word	Definition
D1. Rehabilitation[1]	A set of interventions designed to optimize functioning and reduce disability in individuals with health conditions in interaction with their environment. *WHO https://www.who.int/news-room/fact-sheets/detail/rehabilitation*
D2. Prevention[1]	Activities that aim to reduce risk factors for disease or illness. These activities can focus on preventing risk factors (*primary prevention*), preventing progression to disease or illness once a risk factor(s) exists (*secondary prevention*), and/or improving function and reducing disability in persons diagnosed with a disease or illness (*tertiary prevention*). Oleckno WA. Epidemiology: Concepts and Methods: Waveland Press Inc. 2008
D3. Structural Osteoarthritis[2]	OA defined by the presence of structural features on radiograph, MRI or ultrasound, which reach an 'expert consensus threshold' of magnitude and character to be termed OA.
D4. Symptomatic Osteoarthritis[2]	OA defined by consensus-based clinical signs (e.g., age ≥45, crepitus, restricted range of motion, bony enlargement) and symptoms (e.g., activity related joint pain, either no morning knee stiffness or stiffness ≤30 minutes) that are associated with functional or quality-of-life decrements with or without the presence of structural features on radiography, MRI, or ultrasound. Zhang et al 2010, Peat t al 2006, https://www.nice.org.uk/guidance
D5. Injury[3]	Disruption to the body induced by a singular or repetitive event (e.g., joint trauma).
D6. Post-traumatic Osteoarthritis[3]	OA that develops after joint trauma (i.e., disruption of a joint induced by a singular or repetitive event), and is associated with altered biology or pathophysiology (e.g., structural features), symptoms (e.g., pain) and functional or quality-of-life decrements.
D7. Pre-PTOA[3]	Pre-PTOA is a state of heightened OA risk after joint trauma, but where the definitions for structural or symptomatic PTOA are not fulfilled. Pre-PTOA may include evidence of cartilage or meniscal defects on magnetic resonance imaging and/or early symptoms such as joint-related pain leading to functional modifications.
D8. Early-onset PTOA[4]	OA that develops following joint trauma in youth and young adults (e.g., ≤45 years of age) and is associated with pathology, symptoms and functional or quality-of-life decrements.
D9. Gender	Socially constructed roles, behaviours, expressions and identities of girls, women, boys, men, and gender diverse people. It influences how people perceive themselves and each other, how they act and interact, and the distribution of power and resources in society. *https://cihr-irsc.gc.ca/e/48642.html*
D10. Sex	A set of biological attributes in humans and animals. It is primarily associated with physical and physiological features including chromosomes, gene expression, hormone levels and function, and reproductive/sexual anatomy. Sex is usually categorized as female or male but there is variation in the biological attributes that comprise sex and how those attributes are expressed. *https://cihr-irsc.gc.ca/e/48642.html*
D11. Disease	The underlying biology and pathophysiology of a health condition.
D12. Illness	A person's experience of a health condition.
D13. Function (physical)	Body functions, activities and involvement in life situations that require moving around and performing activities. *https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health*
D14. Functional (physical) Performance	The action of carrying out or accomplishing a movement, movement task or movement activity.
D15. Functional (physical) Impairment	*A* decrement in physical functioning at the body level. *https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health*
D16. Activity Limitation (physical)	A decrement in physical functioning at a person level. *https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health*

D17. Participation Restriction (physical)	A decrement in physical functioning at a societal level. *https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health*
D18. Credibility	The quality of being trusted, convincing or believable.
D19. Health Burden	The impact of a health problem as measured by financial (years of life lived with disability, disability adjusted life years), mortality, morbidity (e.g., pain, functional or HRQOL decrements), or other indicators.
D.20 Health-related Quality of Life (HRQOL)	A person's perception of their 'health' well-being. HRQOL is a multifactorial construct that consists of the physical, psychological, and social aspects of health and is influenced by an individual's perceptions, experiences, expectations, and beliefs. Solan et al 2008
D.21Muscle Function	An overarching term that refers to the capacity of a muscle to do work. It includes; strength (force), torque, power, endurance and rate of force development.
D.22 Muscle Strength	The ability of a muscle to produce tension and a resulting force • Isometric: a change in muscle tension with no change in muscle length • Isotonic: a change in muscle length with a given muscle tension • Isokinetic: a change in muscle length and tension with a set contraction speed • Slow speed: 60, 90 and 120 deg/s • High speed: 180 and 300 deg/s Biodex Medical System. System 4 Clinical Resources Manual. Isokinetic Testing and Data Interpretation
D.23 Muscle Power	The ability of a muscle to produce a force quickly (force x velocity (distance/time)) = rate of work).
D.24 Muscle Endurance	The ability of a muscle to contract repeatedly against a load, generate and sustain tension and resist fatigue over a period of time.
D.25 Neuromuscular Control Exercises	Activities that aim to enhance the optimal unconscious neurological and motor responses required for joint, limb and whole-body control of efficient postures and movement (e.g., balance, proprioceptive, readiness of response).
D.26 Plyometrics	Activities that involve a rapid resisted eccentric muscle contraction immediately followed by a rapid resisted concentric contraction (reversal of movement) of the same muscle aimed at improving muscle power.

Definitions 1-8 were discussed at the first consensus meeting, the remaining definitions (9-26) were provided for reference only.

3. Draft Recommendations Discussed at Consensus Meetings 2-6

Clinical Recommendations for Discussion

Abbreviations: ACL (anterior cruciate ligament), ACLR (ACL reconstruction), GRADE (Grading of Recommendations Assessment, Development and Evaluation approach), GROC (global rating of change), PASS (patient acceptable symptom state), PTOA (post-traumatic osteoarthritis)

Topic	Clinical Recommendation	Evidence Level
Who to Target?	C1a. Persons with single (i.e., cruciate ligament, collateral ligament, meniscus, chondral, fracture or dislocation) AND multi-structure (i.e., ACL with concomitant injuries, and patellar dislocation with chondral injuries) knee injuries are at elevated risk of symptomatic knee PTOA.	Moderate (GRADE)[1]
	C1b. Persons with ACL tears, meniscal tears, intra-articular tibiofemoral fractures, patellar dislocations with chondral lesions, or ACLR with partial or total meniscectomy have the most elevated risk of symptomatic knee PTOA.	Moderate (GRADE)[1]
	C1c. Persons with elevated risk of symptomatic knee PTOA experiencing knee-related symptoms and/or functional impairments should be priority targets to prevent osteoarthritis.	Expert opinion

Topic	Clinical Recommendation	Evidence Level
What to Target to Prevent Knee PTOA and When	C2a. Efforts to prevent ***symptomatic knee PTOA*** should promote knee health through:	Expert opinion[2]
	i. Informational support *(e.g., medium and long-term impact of knee injuries on physical, mental and social health, explain PTOA and the elevated risk, self-monitoring function, benefits of exercise, adjusting exercise prescription, debunk myths related to early ACLR, brace use and avoiding weight-bearing, when to seek healthcare support)*	
	ii. Facilitating self-management [a]	
	iii. Mitigating established modifiable risk factors for non-traumatic OA *(i.e., physical activity and exercise-therapy strategies to minimize unhealthy adiposity, leg muscle impairments and sedentary non-weight-bearing behaviours)*	
	iv. Person-centred goals [a]	
	C2b. Efforts to prevent ***symptomatic knee PTOA***:	Expert opinion[2]
	i. commence at the time of knee injury (as possible)	
	ii. continue across the lifespan	

Topic	Clinical Recommendation	Evidence Level
What to Do – Approach (ACL Tear)	C3a. After an ACL tear (barring any complications):	
	i. all persons should be offered and participate in goal-based exercise-therapy rehabilitation until they: a. reach and sustain what they report is an acceptable functional level or, b. cannot achieve an acceptable functional level without activity-related knee instability (i.e., giving way) despite sufficient muscle function	Low[3 4] (GRADE) Expert opinion
	ii. a person's decision to undergo ACLR, should be informed by an orthopaedic surgeon, rehabilitation professional, and other relevant stakeholders (e.g., family, coach) as appropriate.	Expert opinion
	C3b. ACLR rehabilitation should:	
	i. be goal or criterion-based	Expert opinion[5]
	ii. feature shared decision-making	Expert opinion[6]
	iii. begin with structured in-person rehabilitation and progress to structured home (gym)-based rehabilitation	Moderate (GRADE)[3]
What to Do - Core Rehabilitation Treatment (ACLR)	C3c. ACLR rehabilitation should progress through:	
	i. weight-bearing (WB) and range of motion (ROM) exercises	Expert opinion[5]
	ii. open and closed kinetic chain resistance exercises targeting the quadriceps and hamstring muscles	Moderate (GRADE)[3]
	iii. lower limb neuromuscular control exercises	Very low (GRADE)[3]
	iv. lower limb plyometrics	Very low (GRADE)[4]
What to Do - Adjunct Rehabilitation Treatment ACLR	C3d. ACLR rehabilitation can include the following adjunct treatments to improve quadriceps strength:	
	i. neuromuscular electrical stimulation	Moderate (GRADE)[3]
	ii. blood-flow restriction training	Very low (GRADE)[3]
	iii. whole-body vibration	Very low (GRADE)[3]
	C3e. ACLR rehabilitation should not include the following adjunct treatments as there is evidence that they are not beneficial:	
	i. continuous passive motion	Very low (GRADE)[3]
	ii. knee bracing	Moderate (GRADE)[3]
	C3f. Psychological interventions (i.e., guided imagery, relaxation, coping modelling and visual imagery) can improve anxiety and fear after ACLR.	Low (GRADE)[3]
When – Rehabilitation Treatment (ACLR)	C4a. After ACLR	
	i. Weight bearing and range of motion exercises should start immediately	Expert opinion[5]
	ii. open and closed kinetic chain exercises targeting the quadriceps and hamstring muscles should start within the first month	Moderate (GRADE)[3]
	iii. if used, adjunct rehabilitation treatments (e.g., neuromuscular electrical stimulation, blood-flow restriction, plyometrics) to improve quadriceps strength should start within the first 2 months	Very Low (GRADE)[3]

Topic	Clinical Recommendation	Evidence Level
What to Monitor	C5a. Core domains to monitor after knee injury include:	Systematic review & Expert consensus[7 8]
	i. pain	
	ii. physical function (including self-reported function, functional performance and/or muscle function)	
	iii. knee-related quality of life	
	iv. health-related quality of life including physical and mental aspects	
	v. return to sport readiness	
	C5b. Additional domains that may be important for clinicians to monitor after knee injury include:	Expert consensus[7] Expert opinion[6 9]
	i. participation in meaningful physical activities and sport	
	ii. participation in occupation	
	iii. psychological considerations (e.g., fear, frustration, depression)	
	iv. sleep (e.g., quantity and quality as appropriate)	
	v. fatigue	
	vi. social /community participation	
	C5c. After knee injury, diagnostic imaging is only used if it will inform treatment planning	Expert consensus[10]

Topic	Clinical Recommendation	Evidence Level
How to Monitor - PROMs	C6a. Recommended PROMs for use after knee injury include (in alphabetical order):	Systematic review[8 11]
	i. to assess PAIN: • Numerical Rating Scale (NRS) • Visual Analogue Scale (VAS) • Knee injury and Osteoarthritis Outcome Score Pain subscale ($KOOS_{pain}$)	NRS (Expert opinion) VAS (Expert opinion) $KOOS_{pain}$ (COSMIN 2/8 positive scores)[8]
	ii. to assess PHYSICAL FUNCTION: • Knee injury and Osteoarthritis Outcome Score Function in Sport and Recreation subscale ($KOOS_{SR}$) • International Knee Documentation Committee Subjective Form (IKDC-SF)	ACL Tear $KOOS_{SR}$ (COSMIN 2/8 positive scores)[8] IKDC-SF (COSMIN 3/8 positive scores)[8] Meniscus Tear IKDC-SF (COSMIN 2/8 positive scores)[12]
	iii. to assess knee-related QUALITY OF LIFE: • Knee injury and Osteoarthritis Outcome Score QOL subscale ($KOOS_{QOL}$: single and multi-structure injuries) • ACL Quality of Life Score (ACL QOL; ACL Tear only) • Western Ontario Meniscal Evaluation Tool (WOMET; Meniscus tear only)	$KOOS_{QOL}$ (COSMIN 2/8 positive scores)[8] ACL QOL (COSMIN 3/8 positive scores)[8] WOMET (COSMIN 4/8 positive scores)[12]
	iv. to assess health-related QUALITY OF LIFE after knee injury: • Short-form 36 (SF-36)	Expert Opinion[9]
	v. to assess knee-related COGNITIVE BEHAVIOURAL FACTORS*: • ACL Return to Sport Index (ACL RSI; ACL Tear only) • Knee Self-Efficacy Scale (K-SES) • Tampa Scale of Kinesiophobia 11 or 17 (TSK-11 or TSK-17)	ACL-RSI (COSMIN 6/8 positive scores)[8] K-SES (Expert opinion) TSK-17, TSK-11 (Expert opinion)

Topic	Clinical Recommendation	Evidence Level
How to Monitor - Muscle Function	C6b. Recommended measures of muscle function after knee injury are peak knee extensor and flexor strength tests.	Expert Opinion[13 14]
	C6c. Measure peak knee extensor and flexor strength in clinical settings with the following tests (listed most to least rigorous); i. Concentric isokinetic computerised dynamometry (>60°/s) ii. Isometric Hand-Held Dynamometry* (HHD, same assessor) estimate one repetition maximum (1RM) iii. Concentric isotonic 1RM with weight machine (knee extension or prone leg curl) **As HHD can underestimate strength, it is important to secure the femur, have the patient push into resistance generated by a fixed belt, and for re-assessment to be conducted by the same assessor. 1RM should be based on the average of at least two measures of maximum effort. Isometric scores are not interchangeable with isokinetic or isotonic scores.*	Extensor (isokinetic ≥60°/s) GRADE[13] + Very low (Intra-rater reliability) + Moderate (Construct validity) Flexor (isokinetic 60-120°/s) GRADE[13] + Very low (Intra-rater reliability) - Moderate (Construct validity Extensor/Flexor (isotonic) GRADE[13] + High (Criterion validity) Extensor (isometric) GRADE[13] + Moderate (Intra-rater reliability) - Very low (Inter-rater reliability) Extensor/Flexor (isotonic) GRADE[13] + High (Criterion validity)
How to Monitor - Functional Performance	C6d. Recommended measures of functional performance after a knee injury are hop performance tests.	Expert opinion
	C6e. After knee injury, assess hop performance with:	
	i. a battery of hop tests	
	ii. the hop battery should include tests that assess forward (single and repeated), lateral and vertical hopping	
	C6f. Recommended hop tests for use after knee injury include (in alphabetical order): • Crossover Hop Test (CH) • Single Leg Hop Test (SLH) • Triple Hop Test (TH) • 6-meter Timed Hop Test (6mTH) • Vertical hop (VH)	CH GRADE[15] + Moderate (Intra-rater reliability) + Low (Construct validity) + Low (Responsiveness) SLH GRADE[15] + High (Intra-rater reliability) + Low (Construct validity) + Low (Responsiveness) TH GRADE[15] + Very low (Intra-rater reliability) + Moderate (Construct validity) - Low (Responsiveness) VH GRADE[15] + Moderate (Intra-rater reliability) + Moderate (Construct validity) 6mTH GRADE[15] + Moderate (Intra-rater reliability) + Low (Construct validity) + Low (Responsiveness)

+ (sufficient measurement property), - (insufficient measurement property) as per the COSMIN

Topic	Clinical Recommendation	Evidence Level
Interpreting Outcome Domain Change and Status	C7a. To interpret a change in an outcome domain, persons who have had a knee injury should be asked if they have noticed a meaningful change in the domain. *For example: 'Have you noticed a meaningful change in your insert domain (e.g., knee pain) over the last insert time period?'*	GROC concept[16] PASS concept[17] Expert opinion
	C7b. To assess the acceptability of the current state of an outcome domain, persons who have had a knee injury should be asked if they feel their current state is satisfactory. *For example: 'Taking into consideration all you do in a typical day, is the current state of your insert domain (e.g., knee pain) satisfactory'?*	
	C7c. Clinicians should review individual PROM items responses of persons who have had a knee injury to identify what factors might be important to their experience of an outcome domain. *For example: Is a person's knee pain primarily due to twisting, and/or fully straightening the knee bending the knee, walking on a flat surface, navigating stairs, sleeping, sitting, lying, standing.'*	
	C7d. Clinicians should ask persons who have had a knee injury about individual PROM item responses to better understand their experience of an outcome domain. *For example (KOOS Q3): 'You indicate you are severely troubled by a lack of knee confidence, can you tell me a bit more about that? What activities or situations do you feel confident and lack confidence?'*	
	C7e. To report/record on an outcome domain (health record or report) for a person who has had a knee injury, the following information should be recorded:	
	i. The baseline and change (either increase or decrease) in the outcome *For example: insert name started at xx and had an 8-point increase in their Knee injury and Osteoarthritis Outcome Score Pain subscale over insert time period*	
	ii. If the person felt the change in the outcome was meaningful *For example: insert name felt that the increase was meaningful*	
	iii. If the person feels that their current state of an outcome is satisfactory/acceptable *For example: insert name reports that after taking into account all they have to do in a typical day, the current state of their insert domain is not acceptable.*	

Research Recommendations for Discussion

Topic	Research Recommendation
Overarching Research Considerations for knee PTOA	R1a. Research about PTOA should prioritize ***symptomatic*** definitions of OA (structural + symptoms or functional impairment) over ***structural*** definitions.
	R1b. Consensus on how to operationalize, measure (including timepoints) and handle definitions of ***symptomatic and structural knee PTOA*** are needed to facilitate meta-analysis.
	R1c. Research investigating the influence of sex, gender, race, and other social determinants of health on the development of PTOA is needed to understand and address disparity in outcomes across populations.
Study Design – Risk Factors for Knee OA after Injury	R2a. Research investigating risk factors for ***symptomatic knee PTOA*** should consider both ACL tear and non-ACL tear related injuries.
	R2b. Structural knee OA data should be reported by joint compartment (i.e., medial tibiofemoral, lateral tibiofemoral and patellofemoral) and overall knee joint.
Study Design – Interventions after Knee Injury	R2c. Research studies including follow-up beyond 5 years would assist in better understanding if interventions can reduce the risk of ***symptomatic*** and ***structural OA*** after knee injury.

Topic	Research Recommendation	Evidence Level
Study Design - Outcome Domains	R3a. Intervention and observational studies of persons at risk of ***symptomatic knee PTOA*** should consider assessing the following core outcome domains:	Systematic review & Expert consensus[7 8]
	i. pain	
	ii. physical function including self-reported function, functional performance and muscle function	
	iii. knee-related quality of life	
	iv. health-related quality of life including physical and mental aspects	
	v. general overall self-assessment	
	vi. adverse events	
	R3b. Depending on the research question, it may also be important to assess:	Expert consensus[7] Expert opinion[6 9 10]
	i. re-injury and subsequent injury	
	ii. return to and participation in meaningful activities*	
	iii. return to and participation in one's occupation	
	iv. psychological considerations (e.g., fear, frustration, depression)	
	v. sleep	
	vi. fatigue	
	vii. joint structure (e.g., imaging)	
	viii. molecular molecules (e.g., inflammatory biomarkers)	
	ix. comorbidities	
	x. social /community participation	
	xi. economic	
Study Design – Follow-up	R3d. Consider monitoring individuals at elevated risk of ***symptomatic knee PTOA*** across the entire timespan from injury to any OA diagnosis.	Systematic review & Expert opinion[2 8]

Topic	Research Recommendation	Evidence Level
Study Design - PROMs	R4a. In the knee PTOA field, meaningful PROM thresholds:	Expert opinion[11]
	i. Should be used to evaluate individual pre- to post-treatment change in score	
	ii. Should not be used as a primary outcome or to calculate sample sizes to assess group level differences	
PROM Selection	R4b. Recommended PROMs for use after knee injury include:	Systematic review[8 11] / Expert opinion
	i. to assess PAIN: • Numerical Rating Scale (NRS) • Visual Analogue Scale (VAS) • Knee injury and Osteoarthritis Outcome Score Pain subscale ($KOOS_{pain}$)	NRS (Expert opinion) VAS (Expert opinion) $KOOS_{pain}$ (COSMIN 2/8 positive scores) [8]
	ii. to assess PHYSICAL FUNCTION: • Knee injury and Osteoarthritis Outcome Score Function in Sport and Recreation subscale ($KOOS_{SR}$) • International Knee Documentation Committee Subjective Form (IKDC-SF)	ACL Tear $KOOS_{SF}$ (COSMIN 2/8 positive scores)[8] IKDC-SF (COSMIN 3/8 positive scores)[8] Meniscus Tear IKDC-SF (COSMIN 2/8 positive scores)[12]
	iii. to assess knee-related QUALITY OF LIFE: • Knee injury and Osteoarthritis Outcome Score QOL subscale ($KOOS_{QOL}$) • Anterior Cruciate Ligament Quality of Life Score (ACL QOL; ACL Tear only) • Western Ontario Meniscal Evaluation Tool (WOMET; Meniscus tear only)	$KOOS_{QOL}$ (COSMIN 2/8 positive scores)[8] ACL QOL (COSMIN 3/8 positive scores)[8] WOMET (COSMIN 4/8 positive scores)[12]
	iv. to assess health-related QUALITY OF LIFE: • SF-12 (physical and mental components) • SF-36 (bodily pain) • EQ-5D Index	Expert opinion[9]
	v. to assess knee-related COGNITIVE BEHAVIOURAL factors • ACL RSI • K-SES • TSK-17/TSK-11	ACL-RSI (COSMIN 6/8 positive scores)[8] K-SES (Expert opinion) TSK-17, TSK-11 (Expert opinion)
	vi. to assess PATIENT GLOBAL ASSESSMENT: • Patient Acceptable Symptom State (PASS) • Treatment Failure (TF) • Global Rate of Change Score (GROC)	PASS,[17] TF,[18] GROC[16] (Expert opinion)[11]

Topic	Research Recommendation	Evidence Level
PROM Interpretation	R4c. Researchers can be somewhat confident that the following group level PROM score changes are meaningful after a knee injury:	Expert opinion[11]
	i. PAIN PROM scores: • NRS and VAS: change of 1.5/10 • $KOOS_{Pain}$: change of 12/100	NRS[19] VAS[19] $KOOS_{Pain}$ (Low credibility)[11]
	i. SYMPTOMS PROM scores: • $KOOS_{symp}$: change of 6/100 (ACL tear), 12/100 (meniscus surgery)	$KOOS_{Symp}$ (Low credibility)
	ii. PHYSICAL FUNCTION PROM scores: • $KOOS_{SR}$: change of 22/100 (ACL tear), 17/100 (meniscus tear) • IKDC-SF: change of 16/100 (ACL tear), 11/100 (meniscus tear)	ACL Tear $KOOS_{SR}$ (Low credibility)[11 16] IKDC-SF (Low credibility)[11 20] Meniscus Tear IKDC-SF (Very Low/Low credibility)[11 21]
	iii. Knee-related QUALITY OF LIFE PROM scores: • $KOOS_{QOL}$: change of 18/100 • ACL QOL: change of 9/100 • WOMET: change of 15/100	$KOOS_{QOL}$ (High Credibility)[11 16] ACL QOL (Very Low credibility)[22] WOMET (Very Low credibility[12 23]
	iv. Health-related QUALITY OF LIFE PROM scores: • SF-36 bodily pain: change of 8/100 • Sf-12: change of 5.1/100 (PCS), 4.3/100 (MCS) • EQ-5D Index: change of 0.32	Expert Opinion
	v. Knee-related COGNITIVE BEHAVIOURAL factor scores: • ACL RSI: change of 3/100 • K-SES: change of 15/100 • TSK-11: change of 5 (ACL tear) • TSK-17: change of 1 (ACL tear), 8 (meniscus tear)	ACL Tear ACL RSI (Low credibility)[11 24] K-SES (Expert opinion) TSK-17 (ACL – Low credibility)[11 25] TSK-11 (Expert opinion) Meniscus Tear TSK-17 (meniscus - Expert Opinion)
	vi. Patient Global Assessment (PASS): • $KOOS_{Pain}$: change of 93/100 (ACLR), 81/100 (meniscal surgery) • $KOOS_{SR}$: change of 88/100 (ACLR,) 80/100 (meniscal surgery) • $KOOS_{QOL}$: change of 78/100 (ACLR), 57/100 (meniscal surgery) • IKDC-SF: change of 85/100 (ACLR), 69/100 (meniscal surgery)	ACLR KOOS[11 26] IKDC-SF, ACLR[11 26] Meniscus Surgery KOOS[11 21 27] IKDC-SF[11 21]

Topic	Research Recommendation	Evidence Level
How to Monitor – Muscle Function	R5a. The best available measure of muscle function after knee injury are peak knee extensor and flexor strength tests.	Expert opinion[13 14]
	R5b. In order of most to least rigorous, the following tests should be used to measure peak knee extensor and flexor strength in clinical settings; i. Concentric isokinetic computerised dynamometry (>60°/s) ii. Isometric Hand-Held Dynamometry* (HHD, same assessor) one repetition maximum (1RM) iii. Concentric isotonic 1RM with weight machine (knee extension or prone leg curl) **HHD assessment of isometric knee extensor and flexor strength can underestimate strength and overestimate limb symmetry index (LSI). Isometric scores are not interchangeable with isokinetic or isotonic scores.*	Extensor (isokinetic ≥60°/s) GRADE[13] + Very low (Intra-rater reliability) + Moderate (Construct validity) Flexor (isokinetic 60-120°/s) GRADE[13] + Very low (Intra-rater reliability) - Moderate (Construct validity Extensor/Flexor (isotonic) GRADE[13] + High (Criterion validity) Extensor (isometric) GRADE[13] + Moderate (Intra-rater reliability) - Very low (Inter-rater reliability) Extensor/Flexor (isotonic) GRADE[13] + High (Criterion validity)
How to Interpret – Muscle Strength	R5c. The following change or variation* in muscle strength scores can GUIDE interpretation of a meaningful change after knee injury. • Peak concentric knee extensor strength (60°/s): variation of 23% • Peak concentric knee extensor strength (180°/s): variation of 8% • Peak concentric knee extensor normalised (body weight) strength: change of 1.7% • Peak concentric knee extensor strength LSI: change of 10.5% • Peak concentric knee flexor strength (60°/s and 180°/s): variation of 9%	GRADE[13] Very low

+ (sufficient measurement property), - (insufficient measurement property) as per the COSMIN

Topic	Research Recommendation	Evidence Level
How to Monitor - Functional Performance	R6a. The best available measure of functional performance after a knee injury is hop performance.	Expert Opinion
	R6b. After knee injury, hop performance should be assessed with:	
	i. a battery of hop tests	
	ii. the hop battery should include tests that assess forward (single and repeated), lateral and vertical hopping	
	R6c. Recommended hop tests for use after knee injury include (in alphabetical order): • Crossover Hop Test (CH) • Single Leg Hop Test (SLH) • Triple Hop Test (TH) • Vertical hop (VH) • 6-meter Timed Hop Test (6mTH)	CH GRADE[15] + Moderate (Intra-rater reliability) + Low (Construct validity) + Low (Responsiveness) SLH GRADE[15] + High (Intra-rater reliability) + Low (Construct validity) + Low (Responsiveness) TH GRADE[15] + Very low (Intra-rater reliability) + Moderate (Construct validity) - Low (Responsiveness) VH GRADE[15] + Moderate (Intra-rater reliability) + Moderate (Construct validity) 6mTH GRADE[15] + Moderate (Intra-rater reliability) + Low (Construct validity) + Low (Responsiveness)
How to interpret Functional Performance	R6d. The following change in hop performance can GUIDE interpretation of a meaningful change after knee injury. • Single Leg Hop Test: change of 6.7%-9.7% (LSI) • Crossover Hop Test: change of 14.6% (LSI) • 6-meter Timed Hop Test: change of 15.5% (LSI) • Triple Hop Test: change of 12.0% (LSI) • Vertical Hop: change of 10% (LSI) *Limb symmetry index (LSI) is influenced by changes performance of both the injured and contralateral leg.*	SLH, CH, 6mTH, TH GRADE Very low[15] VH Expert opinion

+ (sufficient measurement property), - (insufficient measurement property) as per the COSMIN

4. Evidence Summary for Review Prior to Consensus Meetings 2-6

Meeting 2: Risk factors for knee osteoarthritis after knee trauma: a systematic review and meta-analysis of randomised controlled trials and cohort studies for the OPTIKNEE consensus

Objective: Identify risk factors for osteoarthritis following knee trauma.

Design: Systematic review and meta-analyses that estimated the odds of osteoarthritis for risk factors assessed in four or more studies using random-effects models. Remaining risk factors underwent semi-quantitative synthesis. The modified GRADE approach for prognostic factors guided assessment.

Data Sources: MEDLINE, EMBASE, CENTRAL, SPORTDiscus, CINAHL searched from inception to 09-2021.

Eligibility: Randomized Controlled Trials (RCT) and cohort studies assessing risk factors for symptomatic or structural osteoarthritis in persons with knee trauma, mean injury age ≤30 years, and minimum 2-year follow-up.

Results: Across 66 included studies, 81 unique potential risk factors were identified. High risk-of-bias due to attrition or confounding was present in 64% and 49% of studies, respectively. Semi-quantitative syntheses identified moderate-certainty evidence that cruciate ligament, collateral ligament, meniscal, chondral, dislocation, fracture, and multi-structure injuries increase symptomatic osteoarthritis odds. Ten risk factors for structural osteoarthritis underwent meta-analysis (sex, rehabilitation for ACL tear, ACL reconstruction (ACLR), ACLR age, ACLR body mass index, ACLR graft source, ACLR graft augmentation, ACLR+cartilage injury, ACLR+partial meniscectomy, ACLR+total medial meniscectomy). Very-low certainty evidence suggests increased odds of structural osteoarthritis related to ACLR+cartilage injury (OR=2.31; 95%CI 1.35,3.94), ACLR+partial meniscectomy (OR=1.87; 1.45,2.42), and ACLR+total medial meniscectomy (OR=3.14; 2.20,4.48).

Conclusion: Moderate-certainty evidence suggests that various injury types (not just ACL tears) increase symptomatic osteoarthritis odds after knee trauma. Risk factor heterogeneity, limited RCT evidence and inconsistency in risk factors and osteoarthritis definition makes identifying treatment targets for preventing post-traumatic knee osteoarthritis challenging.

What is already known?

- Medial meniscal injury and/or meniscectomy associated with an Anterior Cruciate Ligament (ACL) tear, and isolated meniscal injuries are associated with an increased risk of structural knee osteoarthritis.
- Beyond meniscal injury or meniscectomy, little is known about risk factors for symptomatic or structural knee osteoarthritis after an ACL tear and non-ACL tear related knee trauma.
- Currently, it is unclear if there are modifiable risk factors after knee trauma that can be targeted to prevent symptomatic or structural osteoarthritis.

What are the new findings?

- Non-modifiable risk factors: There is moderate-certainty evidence that various single (cruciate ligament, collateral ligament, meniscus, chondral, fracture or dislocation) AND multi-structure knee injuries (ACL with meniscal injuries, and patellar dislocation with chondral injuries) increase the odds of symptomatic knee osteoarthritis.
- Modifiable risk factors: Significant heterogeneity in potential risk factors assessed, low-certainty of evidence and inconsistency in how risk factors and osteoarthritis are operationalized, measured, and analysed, makes it challenging to identify modifiable risk factors, or treatment targets for preventing symptomatic or structural knee osteoarthritis after knee trauma.
- In the absence of high-certainty evidence of modifiable risk factors for osteoarthritis after knee trauma, the logical attempts to prevent post-traumatic osteoarthritis should include evidence-based injury prevention programs, and addressing modifiable risk factors for non-traumatic osteoarthritis after a wide range of knee injuries (not just ACL tears). This includes physical activity and exercise-therapy strategies to minimize unhealthy adiposity and quadriceps weakness.

Meeting 3: Rehabilitation after anterior cruciate ligament and meniscal injuries: a best-evidence synthesis of systematic reviews for the OPTIKNEE consensus

Objective: Summarise evidence for effectiveness of rehabilitation interventions following anterior cruciate ligament (ACL) and/or meniscal tear.

Design: Overview of systematic reviews with GRADE certainty-of-evidence.

Data sources: MEDLINE, EMBASE, CINAHL, SPORTDiscus, Cochrane Library.

Eligibility criteria: Systematic reviews of randomised controlled trials investigating rehabilitation interventions following ACL and/or meniscal tears in young adults.

Results: We included 22 systematic reviews (142 trials of mostly males) evaluating ACL injured individuals and none evaluating isolated meniscal injuries. We synthesised data from 16 reviews evaluating 12 different interventions. Moderate-certainty evidence was observed for: i) neuromuscular electrical stimulation to improve quadriceps strength; ii) open- vs closed-kinetic-chain exercises to be similarly effective for quadriceps strength and self-reported function; iii) structured home-based vs structured in-person rehabilitation to be similarly effective for quadriceps and hamstring strength and self-reported function; and iv) postoperative knee bracing being ineffective for physical function and laxity. There was low-certainty evidence that: i) preoperative exercise-therapy improves self-reported and physical function postoperatively; ii) cryotherapy reduces pain and analgesic use; iii) psychological interventions improve anxiety/fear; and iv) whole-body vibration improves quadriceps strength. There was very low-certainty evidence that: i) protein-based supplements improve quadriceps size; ii) blood-flow restriction training improves quadriceps size; iii) neuromuscular control exercises improve quadriceps and hamstring strength and self-reported function; and iv) continuous passive motion has no effect on ROM.

Conclusion: The general level of evidence for rehabilitation after ACL or meniscal tear was low. Moderate-certainty evidence indicates that several rehabilitation types can improve quadriceps strength, while brace use has no effect on knee function/laxity.

What is already known?

- Anterior cruciate ligament and meniscal injuries are often associated with a poor outcome – many fail to return to pre-injury level of sport and there is a high risk of re-injury, persistent symptoms and impaired quality of life.
- There is little consensus regarding the optimal components of ACL and meniscal rehabilitation to achieve successful outcomes, leading to substantial heterogeneity in rehabilitation protocols.

What are the new findings?

- Despite 22 systematic reviews including 142 unique RCTs, there is mainly low level of evidence for the effectiveness of ACL rehabilitation interventions to improve symptomatic and functional outcomes.
- The highest level of evidence for ACL rehabilitation in this review (moderate certainty) was observed for: i) neuromuscular electrical stimulation to improve quadriceps strength; ii) open vs closed kinetic chain exercises to be similarly effective for improving quadriceps strength and self-reported function; iii) structured home-based rehabilitation to be similarly effective to structured in-person rehabilitation for improving quadriceps and hamstring strength and self-reported function; and iv) postoperative knee bracing being ineffective for physical function and knee laxity.
- There is an urgent need for high-quality randomised clinical trials with sufficient sample size to improve the overall certainty of evidence.
- There was no evidence identified in this systematic review to inform the rehabilitation of isolated traumatic meniscal injuries in young adults.

Meeting 3: The effects of different management strategies and rehabilitation approaches on knee joint structural and molecular biomarkers following knee injury: a systematic review of randomized controlled trials for the OPTIKNEE consensus

Objectives: To summarize the effectiveness of management strategies and rehabilitation approaches for outcomes related to knee joint structural and molecular biomarkers following ACL and/or meniscal tear.

Design: Systematic review

Data sources: MEDLINE, EMBASE, CINAHL, CENTRAL, and SportDiscus all up to November 3, 2021.

Eligibility criteria: Randomized controlled trials (RCT) investigating the effectiveness of management strategies or rehabilitation approaches for structural and molecular biomarkers of knee joint health following ACL and/or meniscal tear.

Results: We included five RCTs reported in nine papers, all with ACL tear as the primary injury. Two RCTs compared initial management strategies (rehabilitation+early vs optional delayed ACL surgery), reporting on structural biomarkers (radiographic osteoarthritis, cartilage thickness, meniscal damage) in five papers and molecular biomarkers (inflammation, cartilage turnover) in one paper. Three RCTs compared different post-ACL surgery reconstruction (ACLR) rehabilitation approaches (high vs low intensity plyometric exercises, accelerated vs non-accelerated rehabilitation, continuous passive vs active motion), reporting on structural biomarkers (joint space narrowing) in one paper and molecular biomarkers (inflammation, cartilage turnover) in two papers. There was no differences in structural or molecular biomarkers between various post-ACL surgery rehabilitation approaches. One RCT comparing initial management strategies demonstrated that rehabilitation+early ACLR was associated with greater patellofemoral cartilage thinning, elevated inflammatory cytokine response, and reduced incidence of medial meniscal damage over five years compared to no or delayed ACLR.

Conclusion: Very-low certainty evidence suggests that different initial management strategies, but not post-operative rehabilitation approaches may influence structural and molecular biomarkers of knee joint health following ACL tear.

What is already known?

- ACL and meniscal tears are followed by a cascade of structural and molecular alterations that drive the progression of knee osteoarthritis
- Given the uncertainty about how different management strategies or different rehabilitation approaches influence structural and molecular alterations after knee injury, there are questions surrounding the choice of strategy or treatment approach best preserve current and future knee joint health

What are the new findings?

- Rehabilitation with early ACLR may lead to greater patellofemoral cartilage thinning, elevated inflammatory cytokine response, and reduced incidence of medial meniscal damage over five years compared to no or delayed ACLR.
- Different post-ACL surgery rehabilitation approaches (high and low intensity plyometric exercises, accelerated and non-accelerated rehabilitation, and continuous passive/active motion) appear to have similar effect on knee joint health.
- Due to no RCT evidence to inform management strategies or rehabilitation approaches following primary meniscal tears, the current findings are restricted to primary ACL tears.
- Due to the very low certainty of evidence for the effect of different initial management strategies or rehabilitation approaches on structural and molecular biomarkers of knee joint health following knee injury, clinicians should consider costs and the patient's values and preferences to guide treatment decisions.

Meeting 4: The long-term burden of anterior cruciate ligament and meniscal injury: a systematic review and meta-analysis for the OPTIKNEE consensus

Objective: Determine the long-term physical activity, work limitation, health/economic cost, health-related quality-of-life (HRQoL), and disease burden of traumatic anterior cruciate ligament (ACL) and/or meniscal injury.

Design: Random-effects meta-analysis evaluated HRQoL [SF-36/SF-12/VR-12 physical-component-scores (PCS), mental-component-scores (MCS), EQ-5D] stratified by time post-injury, and pooled mean differences (95% CI) between ACL-injured and uninjured controls. Other outcomes were synthesised descriptively. Risk-of-bias (RoB) and certainty of evidence (GRADE) were assessed.

Data sources: MEDLINE, EMBASE, CENTRAL, SPORTDiscus, CINAHL searched inception-22/11/2021.

Eligibility: Studies reporting physical activity, work limitations, health/economic costs, HRQoL or disease burden, ≥2 years post-ACL and/or meniscal injury.

Results: Fifty studies were included (10 high-RoB, 28 susceptible-to-some-bias, 12 low-RoB). Meta-analysis (27 studies, very low certainty of evidence) estimated a pooled mean (95% CI) PCS of 52.4(51.4-53.4) and MCS of 54.0(53.0-55.0) 2-14 years post-ACL injury. Pooled PCS scores were worse >10 years [50.8(48.7-52.9)] compared to 2-5 years [53.9(53.1,54.7)] post-injury. Excluding high-RoB studies, PCS scores were worse in ACL-injured compared to uninjured controls [-1.5(-2.9, -0.1)]. Six studies (low certainty of evidence) informed a pooled EQ-5D score of 0.83(0.81-0.84). ACL injury was associated with significant direct and indirect costs, and early ACL reconstruction may be less cost-effective than rehabilitation. Some individuals experienced prolonged work absenteeism and modified activities >2 years post-ACL injury. Three studies evaluated meniscal injury outcomes.

Conclusion: There is very-low certainty of evidence that PCS scores ≥2 years post-ACL injury are worse than uninjured controls and decline over time, whereas MCS scores remain high. ACL injury can result in prolonged work absenteeism and high health/economic costs.

What is already known?

- ACL and meniscal injury can result in knee pain, reduced knee function, fear of re-injury, sport cessation and poor quality of life in the short term.
- The long-term burden of knee injury on generic constructs, including physical activity, work limitations, health/economic costs, burden of disease, and overall health-related quality-of-life (HRQoL) are less clear.
- It is unclear how generic health constructs compare to uninjured controls or population norms, more than 2 years following traumatic ACL and/or meniscal injury.

What are the new findings?

- Physical aspects of HRQoL >2 years after ACL injury were worse than uninjured controls and declined over time, whereas mental aspects of HRQoL remained high >2 years after ACL injury.
- Some individuals experience a prolonged period of leave from work after ACL injury, and others reduce work intensity or report work limitations >2 years after ACL injury.
- Although people often change the type of activities they participate in after ACL injury, on average, self-reported physical activity levels may be similar to the general population. Research using objective measures of physical activity at a variety of timepoints after injury is needed.
- The long-term cost of knee injury requires further investigation in a variety of countries and health-care systems. Two RCTs found that early ACL reconstruction may be less cost-effective compared to rehabilitation and optional delayed ACLR.
- There is a need for high-quality studies investigating the long-term burden of traumatic meniscal injury.

Meeting 5: Meaningful thresholds for patient-reported outcomes following interventions for anterior cruciate ligament tear or traumatic meniscus injury: an systematic review for the OPTIKNEE consensus

Objective: We synthesized and assessed credibility of thresholds that define meaningful scores for patient-reported outcome measures (PROMs) following interventions for anterior cruciate ligament (ACL) tear or traumatic meniscus injury.

Design: Systematic review and narrative synthesis.

Data sources: We searched five databases, hand-searched references of included studies, and performed citation tracking.

Eligibility: Included studies investigated: Individuals with ACL tear or meniscus injury; mean age <35 years; and PROM thresholds calculated using any method to define a minimal important change (MIC) or a meaningful post-treatment score (Patient Acceptable Symptom State [PASS] or Treatment Failure).

Results: We included 18 studies (15 ACL, 3 meniscus). Three different methods were used to calculate anchor-based MICs across 9 PROMs, PASS thresholds across 4 PROMs, and Treatment Failure for 1 PROM. Credibility was rated 'high' for only one study — a MIC of 18 for the Knee injury and Osteoarthritis Outcome Score Quality-of-life (KOOS-QOL) subscale. Where multiple thresholds were calculated among 'low' credibility thresholds in ACL studies, MICs converged to within a 10-point range for KOOS-Symptoms (-1.2-5.4), function in daily living (ADL 0.5-8.1), and QOL (18.3-27.3) subscales, and the International Knee Documentation Committee Subjective Knee Form (7.1-16.2). Other PROM thresholds differed up to 30 points. PASS thresholds converged only in KOOS-ADL for ACL tears (92.3-100), and KOOS-Symptoms (73-78) and KOOS-QOL (53-57) in meniscus injuries.

Conclusion: Meaningful PROM thresholds were highly susceptible to methodological heterogeneity. While PROM thresholds can aid interpretability in research and clinical practice, they should be applied at an individual patient level and cautiously interpreted.

What is already known?

- Considering whether a patient-reported outcome or change score is clinically meaningful is an important aspect of interpreting clinical trials results.
- Selecting a threshold to define as clinically meaningful in treatment of individuals following ACL tear or meniscus injury is challenging as reported thresholds differ due to study design, contextual factors, or calculation methods.

What are the new findings?

- A change of 18 points on the KOOS-QOL subscale should be considered an important change (MIC) 6-24 months following reconstructive surgery for an ACL tear.
- Due to low credibility, we are unable to recommend concrete MIC, PASS and Treatment Failure thresholds for other PROMs used after ACL tear or meniscal injury.
- When selecting MIC, PASS or Treatment Failure PROM thresholds, researchers should carefully weigh factors such as study quality, contextual factors, credibility, calculation method, and how much range among thresholds is acceptable for their specific study question.

Meeting 6: What tests should be used to assess functional performance following anterior cruciate ligament or meniscal injury? A systematic review of measurement properties for the OPTIKNEE consensus

Objectives: To critically appraise and summarise measurement properties of functional performance tests in individuals following anterior cruciate ligament (ACL) or meniscal injury.

Design: Systematic review.

Data sources: Systematic searches were performed in Medline (Ovid), Embase (Ovid), CINAHL (EBSCO), and SPORTSDiscus (EBSCO) on July 07 2021.

Eligibility criteria: Studies evaluating at least one measurement property of a functional performance test including individuals following an ACL tear or meniscal injury with a mean injury age of ≤30 years. The COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) Risk of Bias checklist was used to assess methodological quality. A modified Grading of Recommendations Assessment, Development, and Evaluation (GRADE) assessed evidence certainty.

Results: Thirty studies evaluating 26 functional performance tests following ACL injury were included. No studies were found in individuals with an isolated meniscal injury. Included studies evaluated reliability (n=5), measurement error (n=3), construct validity (n=26), structural validity (n=1), and responsiveness (n=1). The Single Leg Hop and Crossover Hop tests showed sufficient intra-rater reliability (high and moderate certainty evidence, respectively), construct validity (low and moderate certainty evidence, respectively), and responsiveness (low certainty evidence).

Conclusion: Frequently used functional performance tests for individuals with ACL or meniscal injury lack evidence supporting their measurement properties. The Single Leg Hop and Crossover Hop are currently the most promising tests following ACL injury. High-quality studies are required to facilitate stronger recommendations of performance-based outcomes following ACL or meniscal injury.

What is already known?

- Functional performance tests are frequently used in research and clinical practice to assess physical function following knee injury.
- Functional performance tests complement patient-reported outcomes, but consensus on which tests have the best measurement properties and clinical relevance in individuals who have had an anterior cruciate ligament (ACL) tear or meniscal injury are lacking.

What are the new findings?

- A wide variety of functional performance tests have been used following ACL injury, but there is a paucity of evidence about their measurement properties.
- The Single Leg Hop Test and Crossover Hop Test are the highest rated tests for use with individuals that have had an ACL injury and reconstruction, displaying excellent intra-rater reliability, and support for construct validity and responsiveness.
- The 6-meter Timed Hop Test and Triple Hop Test demonstrate good intra-rater reliability and support for construct validity, but insufficient responsiveness.
- There is a paucity of knowledge about the measurement properties of functional performance tests for use after isolated meniscal injury.

Meeting 6: Measurement properties for muscle strength tests following anterior cruciate ligament or meniscal injury – where do we need to go and what tests to use? A systematic review of measurement properties for the OPTIKNEE consensus

Objectives: To critically appraise and summarize the measurement properties of knee muscle strength tests for young individuals with anterior cruciate ligament (ACL) or meniscus injury.

Design: Systematic review.

Data sources: Medline (Ovid), Embase (Ovid), CINAHL (EBSCO), and SPORTSDiscus (EBSCO) on 07 July 2021.

Eligibility criteria: Studies evaluating at least one measurement property of a knee extensor or flexor strength test in individuals with ACL or meniscus injuries at a mean injury age of ≤30 years were included. The COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) Risk of Bias checklist assessed methodological quality and a modified Grading of Recommendations Assessment, Development, and Evaluation (GRADE) assessed evidence certainty.

Results: Thirty different modes, instruments and equipment for muscle strength tests were identified in individuals following an ACL injury (33 studies) or an isolated meniscus injury (one study). Strength tests were assessed for reliability (n=eight), measurement error (n=seven), construct validity (n=25) and criterion validity (n=seven). Isokinetic concentric extensor strength tests were the best rated with good intra-rater reliability and construct validity (very-low and moderate evidence certainty, respectively). Isotonic extensor and flexor strength tests (one repetition maximum, 1RM) showed good criterion validity (high evidence certainty).

Conclusion: This systematic review includes 30 different muscle strength tests for knee extensor and flexor strength tests following ACL injury. More high-quality studies on measurement properties is urgently needed. The isokinetic concentric extensor strength test is currently the most reliable and valid test, and isometric test using HHD could be used by the same rater.

What is already known:

- Knee extensor and flexor strength deficits are common following ACL or meniscus injuries, hence, an important part of clinical and physical examinations.
- Isokinetic computerised dynamometry is considered the gold standard to assess strength, yet handheld dynamometry (HHD) and conventional weight machines are more often available in clinical settings.
- There is a lack of consensus about which strength tests (modes, instruments, equipment, procedures and variables reported) are most clinically applicable and have the best measurement properties
- There is lack of evidence synthesis for strength tests to identify which test to be used in clinical settings and the knowledge gaps on measurement properties to be answered in future high-quality studies.

What are the new findings:

- Studies evaluating measurement properties for different muscle strength tests following ACL or meniscus injuries include a large variety of modes, instruments, equipment, procedures and variables reported, and high-quality studies on measurement properties are scares.
- Isokinetic concentric strength tests are currently the most promising tests to assess extensor strength deficits in individuals with an ACL injury, displaying good intra-rater reliability and construct validity.
- The isometric extensor strength test using HHD offers good intra-rater reliability when a single rater tests consecutive contractions within one session.
- Conventional isotonic weight machines testing one-repetition maximum (1RM) might be a good alternative to computerised isokinetic dynamometry when assessing extensor or flexor strength in a clinical setting.

REFERENCES

1. Whittaker JL, Losciale JM, Juhl CB, et al. Risk factors for knee osteoarthritis after knee trauma: a systematic review and meta-analysis of randomised controlled trials and cohort studies for the OPTIKNEE consensus. *Br J Sports Med* Under Review
2. Whittaker JL, Runhaar J, Bierma-Zeinstra S, et al. A lifespan approach to osteoarthritis prevention. *Osteoarthritis Cartilage* 2021;29(12):1638-53. doi: 10.1016/j.joca.2021.06.015 [published Online First: 2021/09/25]
3. Culvenor AG, Girdwood MA, Juhl CB, et al. Rehabilitation after anterior cruciate ligament and meniscal injuries: a best-evidence synthesis of systematic reviews for the OPTIKNEE consensus. *Br J Sports Med* 2022 doi: 10.1136/bjsports-2022-105495
4. Holm PM, Juhl C, Culvenor AG, et al. Effectiveness of initial management strategies and rehabilitation approaches to improve knee joint structural and biological outcomes after injury: a systematic review of ransomised controlled trials for the OPTIKNEE consensus. *Osteoarthritis Cartilage* Under Review
5. Andrade R, Pereira R, van Cingel R, et al. How should clinicians rehabilitate patients after ACL reconstruction? A systematic review of clinical practice guidelines (CPGs) with a focus on quality appraisal (AGREE II). *Br J Sports Med* 2020;54(9):512-19. doi: 10.1136/bjsports-2018-100310 [published Online First: 2019/06/09]
6. Truong LK, Mosewich AD, Holt CJ, et al. Psychological, social and contextual factors across recovery stages following a sport-related knee injury: a scoping review. *Br J Sports Med* 2020;54(19):1149-56. doi: 10.1136/bjsports-2019-101206 [published Online First: 2020/02/16]
7. Smith TO, Hawker GA, Hunter DJ, et al. The OMERACT-OARSI Core Domain Set for Measurement in Clinical Trials of Hip and/or Knee Osteoarthritis. *J Rheumatol* 2019;46(8):981-89. doi: 10.3899/jrheum.181194 [published Online First: 2019/01/17]
8. Gagnier JJ, Shen Y, Huang H. Psychometric Properties of Patient-Reported Outcome Measures for Use in Patients with Anterior Cruciate Ligament Injuries: A Systematic Review. *JBJS Rev* 2018;6(4):e5. doi: 10.2106/JBJS.RVW.17.00114 [published Online First: 2018/04/11]
9. Filbay SR, Skou ST, Bullock GS, et al. The long-term burden of anterior cruciate ligament and meniscal injury: A systematic review and meta-analysis for the OPTIKNEE consensus. Under Review
10. Emery CA, Whittaker JL, Mahmoudian A, et al. Establishing outcome measures in early knee osteoarthritis. *Nature reviews Rheumatology* 2019;15(7):438-48. doi: 10.1038/s41584-019-0237-3 [published Online First: 2019/06/16]
11. Macri EM, Young JJ, Ingelsrud LH, et al. Meaningful thresholds for patient-reported outcomes following interventions for anterior cruciate ligament tear or traumatic meniscus injury: an OPTIKNEE systematic review. *Br J Sports Med* Under Review
12. Abram SGF, Middleton R, Beard DJ, et al. Patient-reported outcome measures for patients with meniscal tears: a systematic review of measurement properties and evaluation with the COSMIN checklist. *BMJ open* 2017;7(10):e017247. doi: 10.1136/bmjopen-2017-017247 [published Online First: 2017/10/17]
13. Urhausen A, Berg B, Oiestad BE, et al. Measurement properties for muscle strength tests following anterior cruciate ligament or meniscal injury – where do we need to go and what tests to use? A systematic review of measurement properties for the OPTIKNEE initiative. *Br J Sports Med* Under Review
14. Tayfur B, Charuphongsa C, Morrissey D, et al. Neuromuscular Function of the Knee Joint Following Knee Injuries: Does It Ever Get Back to Normal? A Systematic Review with Meta-Analyses. *Sports medicine* 2021;51(2):321-38. doi: 10.1007/s40279-020-01386-6 [published Online First: 2020/11/29]
15. Berg B, Urhausen AP, Oiestad BE, et al. What tests should be used to assess functional performance in youth and young adults following anterior cruciate ligament or meniscal injury? A systematic review of measurement properties for the OPTIKNEE consensus. *Br J Sports Med* 2022 doi: 10.1136/bjsports-2022-105510 [published Online First: 2022/06/14]

16. Ingelsrud LH, Terwee CB, Terluin B, et al. Meaningful Change Scores in the Knee Injury and Osteoarthritis Outcome Score in Patients Undergoing Anterior Cruciate Ligament Reconstruction. *Am J Sports Med* 2018;46(5):1120-28. doi: 10.1177/0363546518759543 [published Online First: 2018/03/09]
17. Tubach F, Ravaud P, Baron G, et al. Evaluation of clinically relevant states in patient reported outcomes in knee and hip osteoarthritis: the patient acceptable symptom state. *Ann Rheum Dis* 2005;64(1):34-37.
18. Barenius B, Forssblad M, Engström B, et al. Functional recovery after anterior cruciate ligament reconstruction, a study of health-related quality of life based on the Swedish National Knee Ligament Register. *Knee Surg Sports Traumatol Arthrosc* 2013;21(4):914-27.
19. Laigaard J, Pedersen C, Ronsbo TN, et al. Minimal clinically important differences in randomised clinical trials on pain management after total hip and knee arthroplasty: a systematic review. *Br J Anaesth* 2021;126(5):1029-37. doi: 10.1016/j.bja.2021.01.021 [published Online First: 2021/03/09]
20. Tigerstrand Grevnerts H, Gravare Silbernagel K, Sonesson S, et al. Translation and testing of measurement properties of the Swedish version of the IKDC subjective knee form. *Scand J Med Sci Sports* 2017;27(5):554-62. doi: 10.1111/sms.12861 [published Online First: 2017/02/17]
21. Maheshwer B, Wong SE, Polce EM, et al. Establishing the Minimal Clinically Important Difference and Patient-Acceptable Symptomatic State After Arthroscopic Meniscal Repair and Associated Variables for Achievement. *Arthroscopy: The Journal of Arthroscopic & Related Surgery* 2021
22. Lafave MR, Hiemstra L, Kerslake S, et al. Validity, Reliability, and Responsiveness of the Anterior Cruciate Ligament Quality of Life Measure: A Continuation of Its Overall Validation. *Clin J Sport Med* 2017;27(1):57-63. doi: 10.1097/JSM.0000000000000292 [published Online First: 2016/01/19]
23. Van Der Wal RJP, Heemskerk BTJ, Van Arkel ERA, et al. Translation and Validation of the dutch western ontario meniscal evaluation tool. *J Knee Surg* 2017;30(04):314-22.
24. Slagers AJ, van den Akker-Scheek I, Geertzen JHB, et al. Responsiveness of the anterior cruciate ligament - Return to Sports after Injury (ACL-RSI) and Injury - Psychological Readiness to Return to Sport (I-PRRS) scales. *Journal of sports sciences* 2019;37(21):2499-505. doi: 10.1080/02640414.2019.1646023 [published Online First: 2019/07/25]
25. Huang H, Nagao M, Arita H, et al. Reproducibility, responsiveness and validation of the Tampa Scale for Kinesiophobia in patients with ACL injuries. *Health and quality of life outcomes* 2019;17(1):150.
26. Muller B, Yabroudi MA, Lynch A, et al. Defining thresholds for the patient acceptable symptom state for the IKDC subjective knee form and KOOS for patients who underwent ACL reconstruction. *The American journal of sports medicine* 2016;44(11):2820-26.
27. Pedersen JR, Roos EM, Thorlund JB, et al. Cut-off values to interpret short-term treatment outcomes after arthroscopic meniscal surgery measured with the Knee Injury and Osteoarthritis Outcome Score. *J Orthop Sports Phys Ther* 2021(0):1-31.

SUPPLEMENTARY FILE 2: Consensus Experts, Primary Affiliation, Role and Involvement

Name	Primary Affiliation	Role	Convene Steering Committee	Develop Guiding Questions	Convene Expert Group	Evidence Synthesis	Generate Consensus Recommendations	Revise Recommendations	Rate Recommendations
Jackie Whittaker	University of British Columbia, Canada	steering committee review lead author	✓	✓	✓	✓	✓	✓	✓
Adam G. Culvenor	La Trobe University, Australia	steering committee review lead author	✓	✓	✓	✓	✓	✓	✓
Carsten Juhl*	University of Southern Denmark, Denmark	steering committee review co-author	✓	-	-	✓	-	-	-
Kay M. Crossley	La Trobe University, Australia	steering committee review senior author	✓	✓	✓	✓	✓	✓	✓
Ewa M. Roos	University of Southern Denmark, Denmark	steering committee review senior author	✓	✓	✓	✓	✓	✓	✓
Clare Ardern	University of British Columbia, Canada	meeting facilitator	-	-	-	-	-	-	✓
Maxi Miciak	University of Alberta, Canada	patient partner	-	-	-	✓	✓	✓	-
Mick Hughes	North Queensland Physiotherapy Centre, Townsville Australia	clinician partner	-	-	-	✓	✓	✓	-
Bjørnar Berg	Oslo University Hospital, Norway	review lead author	-	-	-	✓	✓	✓	✓
Carolyn A. Emery	University of Calgary, Canada	review senior author	-	-	-	✓	✓	✓	✓
Stephanie R. Filbay	University of Melbourne, Australia	review lead author	-	-	-	✓	✓	✓	✓
Pætur M. Holm	University of Southern Denmark, Denmark	review lead author	-	-	-	✓	✓	✓	✓
Erin M. Macri	Erasmus University Medical Center, Netherlands	review lead author	-	-	-	✓	✓	✓	✓
May Arna Risberg	University of Oslo, Norway	review senior author	-	-	-	✓	✓	✓	✓

Anouk P. Urhausen	Norwegian School of Sport Sciences, Norway	review lead author	-	-	-	✓	✓	✓	✓
Marienke van Middlekoop	Erasmus University Medical Center, Netherlands	review senior author	-	-	-	✓	✓	✓	✓
Alessio Bricca	University of Southern Denmark, Denmark	review senior author	-	-	-	✓	✓	✓	✓
Andrea M. Bruder	La Trobe University, Australia	consensus group member	-	-	-	-	-	✓	✓
Garrett Bullock	Wake Forest School of Medicine, USA	review co-author	-	-	-	✓	✓	✓	✓
Allison M. Ezzat	La Trobe University, Australia	review co-author	-	-	-	✓	✓	✓	✓
Michael A. Girdwood	La Trobe University, Australia	review co-author	-	-	-	✓	✓	✓	✓
Mellissa J. Haberfield	La Trobe University, Australia	review co-author	-	-	-	✓	✓	✓	✓
Mick Hughes	North Queensland Physiotherapy Centre, Australia	clinician partner	-	-	-	✓	-	-	-
Lina H. Ingelsrud	Copenhagen University Hospital, Denmark	review co-author	-	-	-	✓	✓	✓	✓
Karim Kahn	University of British Columbia, Canada	review co-author	-	-	-	✓	✓	✓	✓
Staffan Larsson	Lund University, Sweden	review co-author	-	-	-	✓	✓	-	-
Christina Y. Le	University of Alberta, Canada	review co-author	-	-	-	✓	✓	✓	✓
L. Stefan Lohmander	Lund University, Sweden	review co-author	-	-	-	✓	✓	✓	✓
Justin M. Losciale	University of British Columbia, Canada	review co-author	-	-	-	✓	✓	✓	✓
Matilde Lundberg	University of Southern Denmark, Denmark	review co-author	-	-	-	✓	✓	✓	✓
Maxi Miciak	University of Alberta, Canada	review co-author / patient partner	-	-	-	✓	✓	-	-
Britt E. Øiestad	Oslo Metropolitan University, Norway	review co-author	-	-	-	✓	✓	✓	✓

Brooke Patterson	La Trobe University, Australia	review co-author	-	-	-	✓	✓	✓	✓
Anu M. Raisanen	Western University of Health Sciences, USA	review co-author	-	-	-	✓	✓	✓	✓
Søren Skou	University of Southern Denmark, Denmark	review co-author	-	-	-	✓	✓	✓	✓
André Struglics	Lund University, Sweden	review co-author	-	-	-	✓	✓	-	-
Berend Terluin	Amsterdam University Medical Centre, Netherlands	review co-author	-	-	-	✓	✓	-	-
Jonas B. Thorlund	University of Southern Denmark, Denmark	review co-author	-	-	-	✓	✓	✓	✓
Clodagh M. Toomey	University of Limerick, Ireland	review co-author	-	-	-	✓	✓	✓	✓
Linda K. Truong	University of British Columbia, Canada	review co-author	-	-	-	✓	✓	✓	✓
Belle L van Meer	Erasmus University Medical Center, Netherlands	review co-author / clinician	-	-	-	✓	✓	✓	✓
Thomas J. West	La Trobe University, Australia	review co-author	-	-	-	✓	✓	✓	✓
James J. Young	University of Southern Denmark, Denmark	review co-author	-	-	-	✓	✓	✓	✓

*Steering committee member with expertise in evidence synthesis

SUPPLEMENTARY FILE 3: Consensus Definitions, Clinical Recommendations, and Research Recommendations

Whittaker JL, *et al. Br J Sports Med* 2022;0:1–13. doi: 10.1136/bjsports-2022-106299

1. Definitions

Table 1. Definitions

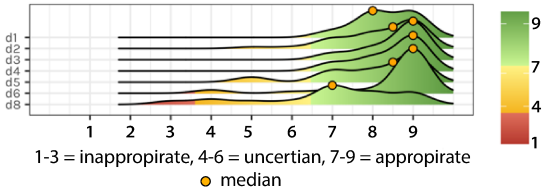
Word		Definition
Core Definitions (voted on)		
D1.	**Rehabilitation**	A health strategy aimed at enabling people with a health condition reach and maintain their optimal physical, sensory, intellectual, psychological and social functional levels. It does so by providing them with the tools needed to attain independence and self-determination.
D2.	**Prevention**	Activities that mitigate modifiable risk factors for disease/illness. These activities can focus on reducing the risk of disease[b]/illness[c] in healthy individuals (primary prevention), early identification and reducing progression to disease or illness in individuals at high risk or with pre-clinical disease/illness (secondary prevention), or improving function and reducing disability in persons diagnosed with a disease/illness (tertiary prevention). In the context of OPTIKNEE, prevention refers to identifying and reducing progression from 'at-risk' to PTOA diagnosis in persons who have had a traumatic knee joint injury (secondary prevention).
D3.	**Structural knee OA**	Knee OA defined by the presence of structural features on imaging, or arthroscopy, which reach an established expert or consensus threshold of magnitude and character to be termed OA (e.g., Kellgren & Lawrence grade, MRI-defined OA based on the MRI Osteoarthritis Knee Score, ICRS cartilage score).
D4.	**Symptomatic knee OA**	Knee OA defined by consensus-based clinical signs and symptoms (e.g., American College of Rheumatology (ACR), National Institutes for Health and Care Excellence (NICE), European League Against Rheumatology (EULAR) definitions), excluding age restrictions, with or without the presence of structural features identified on imaging or arthroscopy.
D5.	**Knee Injury**	Knee joint tissue damage or derangement resulting from a rapid or repeated transfer of kinetic energy.
D6.	**Knee PTOA**	Structural or symptomatic OA that develops following a traumatic knee joint injury.
D8.	**Early-onset knee PTOA**	Symptomatic or structural knee PTOA that develops in youth and young adults (i.e., young people with old knees). NOTE: Similar in concept to 'early-onset' as in 'early-onset' dementia.
Other Definitions (not voted on)		
D9.	**Gender**	Socially constructed roles, behaviours, expressions and identities of girls, women, boys, men, and gender diverse people. It influences how people perceive themselves and each other, how they act and interact, and the distribution of power and resources in society.[a]
D10	**Sex**	A set of biological attributes in humans and animals. It is primarily associated with physical and physiological features including chromosomes, gene expression, hormone levels and function, and reproductive/sexual anatomy. Sex is usually categorized as female or male but there is variation in the biological attributes that comprise sex and how those attributes are expressed[a]
D11.	**Disease**	The underlying biology and pathophysiology of a health condition.
D12.	**Illness**	A person's experience *of a health condition.*
D13.	**Function (physical)**	Body functions, activities and involvement in life situations that require moving around and performing activities[b]
D14.	**Functional (physical) Performance**	The action of carrying out or accomplishing a movement, movement task or movement activity
D15.	**Functional (physical) Impairment**	*A* decrement in *physical functioning at the* body level.[b]
D16.	**Activity Limitation**	A decrement in physical functioning at a person level.[b]
D17.	**Participation Restriction (physical**	A decrement in physical functioning at a societal level.[b]
D18.	**Credibility**	The quality of being trusted, convincing or believable.
D19.	**Health Burden**	The impact of a health problem as measured by financial (years of life lived with disability, disability adjusted life years), mortality, morbidity (e.g., pain, functional or HRQOL decrements), or other indicators.
D20.	**Health-related Quality of Life (HRQOL)**	A person's perception of their 'health' well-being. HRQOL is a multifactorial construct that consists of the physical, psychological, and social aspects of health and is influenced by an individual's perceptions, experiences, expectations, and beliefs. Solan et al 2008

D21.	**Muscle Function**	An overarching term that refers to the capacity of a muscle to do work. Muscle function can be measured by neuromuscular outcomes such as strength (force), torque, power, endurance and rate of force development.
D22.	**Muscle Strength**	The ability of a muscle to produce tension and a resulting force[c] • Isometric: a change in muscle tension with no change in muscle length • Isotonic: a change in muscle length with a given muscle tension • Isokinetic: a change in muscle length and tension with a set contraction speed • Slow speed: 60, 90 and 120 deg/s • High speed: 180 and 300 deg/s
D23.	**Muscle Power**	The ability of a muscle to produce a force quickly (force x velocity (distance/time)) = rate of work)
D24.	**Muscle Endurance**	The ability of a muscle to contract repeatedly against a load, generate and sustain tension and resist fatigue over a period of time.
D25.	**Neuromuscular Control Exercises**	Activities that aim to enhance the optimal unconscious neurological and motor responses required for joint, limb and whole-body control of efficient postures and movement (e.g., balance, proprioceptive, readiness of response).
D26.	**Plyometrics**	Activities that involve a rapid resisted eccentric muscle contraction immediately followed by a rapid resisted concentric contraction (reversal of movement) of the same muscle aimed at improving muscle power.

[a] https://cihr-irsc.gc.ca/e/48642.html
[b] *https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health*
[c] Biodex Medical System. System 4 Clinical Resources Manual. Isokinetic Testing and Data Interpretation

PTOA (post-traumatic osteoarthritis), OA (osteoarthritis)

2. Core Definitions: Voting Distribution



3. Core Definitions: Dissenting Viewpoints

Table 2. Core Definitions: Dissenting Viewpoints

	Word	Definition	Dissenting Viewpoint(s)
D1.	**Rehabilitation**	A health strategy aimed at enabling people with a health condition reach and maintain their optimal physical, sensory, intellectual, psychological and social functional levels. It does so by providing them with the tools needed to attain independence and self-determination.	• A person may not be 'provided' the tools to be independent though this may be the 'aim' • I interpret this to mean that folks universally do not have independence or self-determination prior to rehab, and they universally attain this through the tools provided. I would drop the last sentence.
D2.	**Prevention**	Activities that mitigate modifiable risk factors for disease/illness. These activities can focus on reducing the risk of disease/illness in healthy individuals (primary prevention), early identification and reducing progression to disease or illness in individuals at high risk or with pre-clinical disease/illness (secondary prevention), or improving function and reducing disability in persons diagnosed with a disease/illness (tertiary prevention). In the context of OPTIKNEE, prevention refers to identifying and reducing progression from pre-clinical to post-traumatic osteoarthritis diagnosis in persons who have had a traumatic knee joint injury (secondary prevention).	• Mostly appropriate but can't help feeling "injury" (primary) or "re-injury" (secondary) should be included with disease/illness. • For the secondary prevention definition, I am not sure what "pre-clinical disease/illness" entails. Is this needed? Or can we go with targeting those at high risk? • Not sure if the definition needs to include 'identifying'. • The definition is too long
D3.	**Structural Knee OA**	Knee OA defined by the presence of structural features on imaging, or arthroscopy, which reach an established expert or consensus threshold of magnitude and character to be termed OA (e.g., Kellgren & Lawrence grade, MRI-defined OA based on the MRI Osteoarthritis Knee Score, ICRS cartilage score).	• Add an example for arthroscopy.
D4.	**Symptomatic Knee OA**	Knee OA defined by consensus-based clinical signs and symptoms (e.g., American College of Rheumatology (ACR), National Institutes for Health and Care Excellence (NICE), European League Against Rheumatology (EULAR), Osteoarthritis Research Society International (OARSI) definitions), excluding age restrictions, with or without the presence of structural features identified on imaging or arthroscopy.	• Many consensus-definitions are limited in applicability to PTOA by their age limit criteria • What about ruling out other sources of symptoms in the absence of structural disease.
D5.	**Knee Injury**	Knee joint tissue damage or derangement resulting from a rapid or repeated transfer of kinetic energy.	• 'Normal knee function' only applies to an initial injury with no history prior knee injury. • 'Repeated transfer of energy' implies overuse injuries and not relevant here. Remove the word 'kinetic' as it is not common to non-native English-speaking persons, or persons with no prior biomechanics' knowledge
D6.	**Knee PTOA**	Structural or symptomatic OA that develops following a traumatic knee joint injury.	• PTOA develops 'because' a knee injury occurred. Adding 'because' would signal a cause effect relationship and better delineate PTOA from insidious onset OA. • It would be helpful to have a time frame to differentiate PTOA from early onset PTOA
D7.	**Early-onset Knee PTOA**	Symptomatic or structural knee PTOA that develops in youth and young adults (i.e., young people with old knees). NOTE: Similar in concept to 'early-onset' as in 'early-onset' dementia.	• Early-onset PTOA could occur in a middle-aged adult so 'young people with old knees' is not ideal as part of this definition. • Recommend focusing on time after traumatic injury rather on specific age range. • Early-onset may be better defined as "X amount of time since injury" rather than the age of the individual who has sustained an injury? • Limiting to youth and young adults does not seem appropriate. It implies that PTOA is age related, whereas it is likely related to time post trauma than age. • What we really mean, is an early-in-life incidence of OA, not an earlier onset of PTOA compared to the usual 10-15 years after knee trauma. • I would not limit to "youth and young adults", as early PTOA can happen in adults (i.e., 30-35 years). The key is that the onset is younger than what is typically expected with OA (e.g., 60s) and leads to a greater number of years lived with disability.

4. Clinical Recommendations: Summary of Evidence and Appropriateness Rating

Table 3. Clinical Recommendations: Summary of Evidence and Appropriateness Rating

	Clinical Recommendation	Evidence	Median	Min-Max	Mode	Appropriateness	Votes
Who to target to delay or halt the onset of OA after traumatic knee injury							
C1ai.	Persons with single structure knee injuries (cruciate ligament; collateral ligament; meniscus; chondral; fracture; dislocation) are at elevated risk of *symptomatic knee OA* compared to people without a knee injury.	Moderate (GRADE)[1]	9	7-9	9	Appropriate	32
C1aii	Persons with multi-structure knee injuries (ACL tear with concomitant injury; patellar dislocation with concomitant chondral injury) are at elevated risk of *symptomatic knee OA* compared to people without a knee injury or a single structure knee injury.	Moderate (GRADE)[1]	9	7-9	9	Appropriate	32
C1b.	Knee injuries associated with the most elevated risk of *symptomatic knee OA* include ACL tears, meniscus tears, intra-articular tibiofemoral fractures, and patellar dislocations with concomitant chondral lesions.	Moderate (GRADE)[1]	8.5	5-9	9	Appropriate	32
C1c.	Priority should be given to persons with knee-related symptoms and/or functional impairments that persist beyond the usual knee injury recovery times, or persons with a recurrent injury.[a]	Expert Opinion	7	2-9	7	Appropriate	32
What and when to target to delay or halt the onset of symptomatic knee OA after a traumatic knee injury							
C2a.	Promote knee health through:						
	i. education[a]	Expert opinion[2]	9	5-9	9	Appropriate	32
	ii. self-management[a]	Expert opinion[2]	9	6-9	9	Appropriate	32
	iii. mitigating known modifiable risk factors for re-injury ad non-traumatic OA[a]	Expert opinion[2]	9	6-9	9	Appropriate	32
	iv. person-centered goals[a]	Expert opinion[2]	9	5-9	9	Appropriate	32
C2b.	Efforts to delay or halt the onset of *symptomatic knee OA* after a traumatic knee injury:						
	i. commence at the time of injury (as possible)	Expert opinion[2]	8	3-9	9	Appropriate	32
	ii. continue across the lifespan	Expert opinion[2]	9	5-9	9	Appropriate	32
What to do after and ACL tear *The following are applicable to patients who have had an ACL tear and/or undergone an ACLR; but may not apply to every individual and situation. It is important that the patient and healthcare provider consider the unique features of a patient's injury, the resources available to them and their unique situation when developing a treatment plan.*							
C3a.	First-line treatment of an ACL tear includes:						
	i. education[a]	Expert Opinion[3]	9	4-9	9	Appropriate	34
	ii. exercise therapy-based rehabilitation (see c3c, d and e)	Low[4 5] (GRADE)	9	6-9	9	Appropriate	34
C3b.	The decision to undergo ACLR is:						
	i. delayed at least until there is a 'quiet knee'[b]	Expert opinion[3]	9	4-9	9	Appropriate	34
	ii. considered when a patient cannot achieve their acceptable functional level despite sufficient muscle function[a]	Expert opinion[3]	8	2-9	8	Appropriate	34
	iii. made by the patient and informed by relevant stakeholders[a]	Expert opinion[3]	9	2-9	9	Appropriate	34

C3c.	ACL tear and ACLR rehabilitation:							
	i. incorporate patient preferences	Expert opinion[6,7]	9	6-9	9	Appropriate	34
	ii. are goal and/or criterion-based	Expert opinion[8]	9	6-9	9	Appropriate	34
	iii. begin with supervised rehabilitation and progesses through semi-supervised home(gym)-based rehabilitation to unsupervised home (gym) self-management	Moderate (GRADE)[4] Expert opinion[7]	8.5	5-9	9	Appropriate	34
C3d.	Core components of ACL tear and ACLR rehabilitation include:							
	i. weight-bearing and ROM exercises[a]	Expert opinion[8,7]	9	7-9	9	Appropriate	34
	ii. open and closed kinetic chain lower-limb resistance-based exercises[a]	Moderate (GRADE)[4] Expert opinion[7]	9	6-9	9	Appropriate	34
	iii. lower-limb neuromuscular control exercises[a]	Very low (GRADE)[4] Expert opinion[7]	9	6-9	9	Appropriate	34
	iv. lower-limb plyometrics[a]	Very low (GRADE)[5] Expert opinion[7]	8.5	6-9	9	Appropriate	34
	v. return to work, sport or other physical activity preparation[a]	Expert opinion[3 9]	9	7-9	9	Appropriate	34
	vi. techniques to promote exercise adherence and self-management of knee health[a]	Expert opinion[10]	9	6-9	9	Appropriate	34
	vii. cognitive behavioural techniques[c]	Low (GRADE)[4] Expert opinion[6 7]	8	2-9	9	Appropriate	34
C3e.	ACL tear and ACLR rehabilitation includes the following adjunct treatments to improve quadriceps strength:							
	i. neuromuscular electrical stimulation[a]	Moderate (GRADE)[4] Expert opinion[7]	7	2-9	7	Appropriate	34
	ii. blood-flow restriction training[a]	Very low (GRADE)[4] Expert opinion[7]	5.5	1-9	6	Uncertain	34
	iii. whole-body vibration[a]	Low (GRADE)[4] Expert opinion[7]	4.5	1-9	5	Uncertain	34
C3f.	ACL tear and ACLR rehabilitation **DOES NOT INCLUDE** the following adjunct treatments:							
	i. continuous passive motion	Very low (GRADE)[4]	9	6-9	9	Appropriate	34
	ii. knee bracing	Moderate (GRADE)[4]	7	1-9	9	Appropriate	34
C3g.	The following criteria are achieved prior to returning to pivoting sports after ACL tear or ACLR:							
	i. at least 9-months post ACLR surgery	Expert opinion[3 9]	9	2-9	9	Appropriate	34
	ii. pass a return to sport test battery[a]	Expert opinion[3 9]	9	7-9	9	Appropriate	34

What to monitor after a traumatic knee injury *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Choice of domain(s) will vary based on individual presentation, goals and practicality. Domains are listed in alphabetical order.*								
C4a.	Core domains to monitor after knee injury include:							
	i.	knee-related adverse events[a] (including subsequent knee injury and giving way episodes	Expert consensus[11 12]	9	7-9	9	Appropriate	31
	ii.	knee-related cognitive behavioural factors[a,c]		8	5-9	9	Appropriate	31
	iii.	knee-related quality of life		9	7-9	9	Appropriate	31
	iv.	knee-related pain		9	6-9	9	Appropriate	31
	v.	knee-related symptoms other than pain[a]		9	6-9	9	Appropriate	31
	vi.	physical activity and sport participation[a]		9	6-9	9	Appropriate	31
	vii.	physical function (including self-reported function, functional performance and/or muscle function)		9	6-9	9	Appropriate	31
C4b.	Additional domains that *may* be important for clinicians to monitor after knee injury include:							
	i.	body weight	Expert consensus[11] Expert opinion[6 13]	7	1-9	8	Appropriate	31
	ii.	health-related quality of life (including physical and mental aspects)		8	5-9	9	Appropriate	31
	iii.	mental health[a]		7	2-9	9	Appropriate	31
	iv.	participation in social roles, responsibilities and relationships including occupation, care-giving and community participation[a]		8	3-9	9	Appropriate	31
C4c.	After knee injury, diagnostic imaging is only used if it will inform treatment planning		Expert consensus[14]	9	6-9	9	Appropriate	31

How to Monitor: Patient Reported Outcomes *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Recommended domains can be measured with instruments that measure **multiple domains** or **individual domains.** The instrument choice within each category will vary based on individual presentation, goals, practicality, and instrument availability. Domains and instruments are listed in alphabetical order.*							
C5a.	Recommended methods to monitor **multiple domains** after knee injury include: • IKDC-SKF[d] • KOOS[e] • Western Ontario Meniscal Evaluation Tool (WOMET)[f]	ACL Tear: • IKDC-SKF (COSMIN 3/8)[12] • KOOS (COSMIN 2/8)[12] Meniscus Tear: • IKDC-SKF (COSMIN 2/8)[15] • WOMET (COSMIN 4/8)[15]	9	7-9	9	Appropriate	31
C5b.	Recommended methods to monitor **single domains** after knee injury include: i. cognitive behavioural factors: • ACL Return to Sport after Injury scale (ACL-RSI, ACL Tear only) • Knee Self Efficacy Scale (K-SES) • Tampa Scale of Kinesiophobia (TSK-17 or TSK-11)	ACL-RSI (COSMIN 6/8) [12] K-SES (Expert Opinion) TSK-17, TSK-11 (Expert Opinion)	8	5-9	9	Appropriate	31
	ii. knee-related pain: • Numerical Rating Scale (NRS) • Visual Analogue Scale (VAS)	NRS (Expert Opinion) VAS (Expert Opinion)	9	1-9	9	Appropriate	31
	iii. knee-related quality of life: • ACL QOL score (ACL Tear only)	ACL QOL (COSMIN 3/8)[12]	8	5-9	9	Appropriate	31
	iv. health-related quality of life: • VAS: At this moment, how good or bad is your general/overall health? (0-the worst health you can imagine, 10-the best health you can imagine) • SF-12[g]	Expert Opinion[13]	7	3-9	7	Appropriate	31
	v. mental health[e] • See supplementary file for examples[a]	Expert Opinion[16]	7	1-9	7	Appropriate	31
	vi. participation in social roles, responsibilities and relationships (including occupation, care-giving and community participation) • See supplementary file for examples[a]	Expert Opinion	7	1-9	7	Appropriate	31
	vii. physical activity and sport participation • Physical Activity resumption and frequency[a] • Sport Participation type[a]	Expert Opinion [17]	8	5-9	9	Appropriate	31

How to Monitor: Muscle Function[h] *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Tests should only be performed when it is safe to do so. Method choice may be influenced by individual presentation, goals, practicality, and availability of instruments. Methods are listed in alphabetical order.*							
C6a.	Recommended clinical measures of knee muscle function[h] after knee injury are peak knee extensor and flexor strength.	Expert Opinion[18 19]	9	5-9	9	Appropriate	33
C6b.	Recommended methods to estimate peak knee extensor and flexor strength in clinical settings include: i. Computerised Dynamometry: concentric isokinetic contraction at ≥60°/s	Extensor GRADE[18]: • + Very low (Intra-RR) • + Moderate (Construct validity) Flexor GRADE[18]: • + Very low (Intra-RR) • - Moderate (Construct validity)	8.5	3-9	9	Appropriate	33
	ii. Hand-held Dynamometry[i,j]: isometric 1RM	Extensor GRADE[18]: • + Moderate (Intra-RR) • - Very low (Inter-RR) • - High (Criterion validity) • - High (Construct validity)	7	1-9	7	Appropriate	33
	iii. weight machine (e.g., knee extension or prone leg curl): concentric isotonic 1RM[j]	Extensor/Flexor GRADE[18]: • + High (Criterion validity)	8	4-9	9	Appropriate	33
C6c.	Recommended additional clinical measures of knee muscle function[h] that are important to monitor after knee injury include:						33
	i. knee extensor and flexor endurance	Expert Opinion	7	1-9	7	Appropriate	33
	ii. knee extensor and flexor power	Expert Opinion	8	2-9	7	Appropriate	33
C6d.	Recommended other muscle groups to monitor after knee injury include those in the lower leg, hip and trunk (see supplementary file for examples[a])	Expert Opinion	8	4-9	9	Appropriate	33

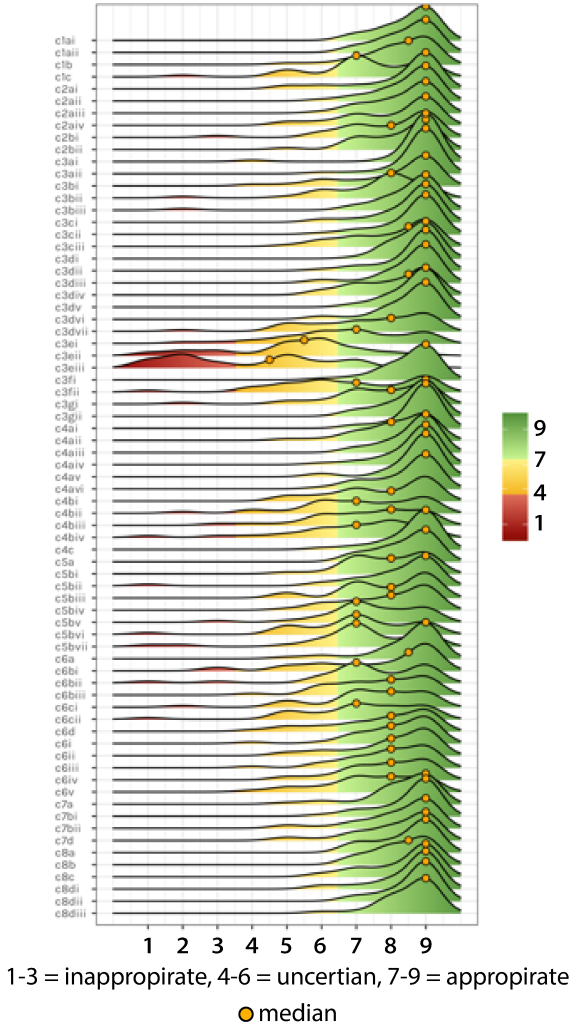
How to Monitor: Functional Performance[k] *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Tests should only be performed when it is safe to do so. Method choice may be influenced by individual presentation, goals, practicality, and availability of instruments. Methods are listed in alphabetical order.*							
C7a.	Recommended clinical measures of functional performance[k] after a knee injury are hop performance.	Expert Opinion[20]	9	5-9	9	Appropriate	33
C7b.	Recommended methods to estimate hop performance in clinical settings include: i. a battery of hop tests (e.g., more than one test)	Expert Opinion[20]	9	5-9	9	Appropriate	33
	ii. the hop battery should include tests that assess forward (single and repeated), diagonal and/or vertical hopping		9	5-9	9	Appropriate	33
C7c.	Recommended hop tests for use after knee injury include[l]: i. Diagonal hop = Crossover Hop Test (CH)[m]	CH GRADE[21]: • + Moderate (Intra-RR) • + Moderate (Construct validity) + Low (Responsiveness)	8	4-9	9	Appropriate	33
	ii. Single forward hop = Single Hop Test (SLH)[m]	SLH GRADE[21]: • + High (Intra-RR) • + Low (Construct validity) + Low (Responsiveness)	8	5-9	9	Appropriate	33
	iii. Repeated forward hop = Triple Hop Test (TH)[m]	TH GRADE[21]: • + Very low (Intra-RR) • + Moderate (Construct validity) - Low (Responsiveness)	8	4-9	9	Appropriate	33
	iv. Vertical hop = Vertical Hop Test (VH)[m]	VH GRADE[21]: • + Moderate (Intra-RR) + Moderate (Construct validity)	8	5-9	9	Appropriate	33
	v. Repeated forward hop = 6-meter Timed Hop Test (6mTH)[m]	6mTH GRADE[21]: • + Moderate (Intra-RR) • + Moderate (Construct validity) - Low (Responsiveness)	8	4-9	9	Appropriate	33
C7d.	Recommended additional clinical measures of functional performance that are important to monitor after knee injury include balance, agility or other task meaningful to the patient.[a]	Expert Opinion	9	5-9	9	Appropriate	33

Interpreting Patient Reported, Muscle Function and Functional Performance Outcome Status and Change							
C8a.	To interpret a change in an outcome domain after knee injury, ask the patient if they have noticed a meaningful change in the domain. *Example: 'Have you noticed a meaningful change in your knee pain, over the last 6 weeks?'*	GROC concept[22] PASS concept[23] Expert Opinion	9	7-9	9	Appropriate	31
C8b.	To assess the current state of an outcome domain after knee injury, ask the patient if they feel their current state is acceptable/satisfactory. *For example: 'Taking into consideration all you do in a typical day, is the current state of your hop performance satisfactory?*		8.5	6-9	9	Appropriate	31
C8c.	To better understand a patient's experience of an outcome domain after a knee injury, ask them about individual PROM item responses. *Example (KOOS Q3): 'You indicate you are severely troubled by a lack of knee confidence, can you tell me a bit more about that? In what situations do you feel confident or lack confidence in your knee?'*		9	6-9	9	Appropriate	31
C8d.	To document an outcome domain for a health record or report, include the following information: i. The baseline and follow-up score, and any change (either improvement or deterioration) in the outcome. *Example: insert name had a 15% improvement in knee extensor strength over 4 weeks, (baseline scores = 25 lbs, follow-up score = 29 lbs*		9	6-9	9	Appropriate	31
	ii. If the patient felt the change in the outcome was meaningful. *Example: insert name felt that the increase was meaningful*		9	7-9	9	Appropriate	31
	iii. If the person feel that their current state of an outcome is acceptable/satisfactory. *Example: insert name reports that after taking into account all they have to do in a typical day, the current state of their knee extensor strength is satisfactory.*		9	6-9	9	Appropriate	31

[a]See attached supplementary file for examples (examples were not be voted on)
[b]Quiet knee = Little to no joint effusion or pain, full passive and active tibiofemoral and patellofemoral range of motion, straight leg raise with little to no extension lag, and little to no limp with gait.[24]
[c]Technqiues that target characteristics of a person that affect performance and learning
[d]Assesses knee-related symptoms, sports activities, function and activities of daily living
[e]Assesses knee-related pain, other symptoms, function in daily living, function in sport and recreation, quality of life
[f]Assesses knee-related physical symptoms, sports, recreation, work, lifestyle, emotions
[g]Licencing requirements apply but may be available through your employer
[h]Muscle function refers to the capacity of a muscle to do work. Muscle function can be measured as strength, power, or endurance.
[i]Hand-held dynamometry assessment of isometric knee extensor and flexor strength can underestimate strength. To obtain the most precise estimate it is important to secure the femur, have the patient push into resistance generated by a fixed belt (not the assessor hand), and for re-assessment to be conducted by the same assessor. Isometric scores are not interchangeable with isokinetic or isotonic scores.
[j]Estimates of 1RM should be based on the average of at least two repeated measures of maximum effort.
[k]Functional performance is the action of carrying out or accomplishing a movement, movement task or movement activity
[l]Insufficient evidence to inform the 'best' test or 'best' order
[m]See supplementary file for test description

+ (sufficient measurement property), - (insufficient measurement property) as per the COSMIN, 1-RM (1 repetition maximum), ACL (Anterior Cruciate Ligament), ACLR (ACL reconstruction), GRADE (Grading of Recommendations, Assessment, Development and Evaluations), OA (osteoarthritis), PROM (patient reported outcome measure), ROM (range of motion), RR (Rater Reliability)

5. Clinical Recommendations: Voting Distribution



6. Clinical Recommendations: Dissenting Viewpoints

Supplementary Table 4. Clinical Recommendations: Dissenting Viewpoints

	Clinical Recommendation	Comments and Dissenting Viewpoints
Who to target to delay or halt the onset of OA after traumatic knee injury		
C1a.	Persons with single structure knee injuries (cruciate ligament; collateral ligament; meniscus; chondral; fracture; dislocation) are at elevated risk of *symptomatic knee OA* compared to people without a knee injury.	• Is this list exhaustive meant to be exhaustive?
C1b.	Persons with multi-structure knee injuries (ACL tear with concomitant injury; patellar dislocation with concomitant chondral injury) are at elevated risk of *symptomatic knee OA* compared to people without a knee injury or a single structure knee injury.	
C1c.	Knee injuries associated with the most elevated risk of *symptomatic knee OA* include ACL tears, meniscus tears, intra-articular tibiofemoral fractures, and patellar dislocations with concomitant chondral lesions.	• Is there specific guidance being provided on usual knee injury recovery times?
C1d.	Priority should be given to persons with knee-related symptoms and/or functional impairments that persist beyond the usual knee injury recovery times, or persons with a recurrent injury.[a]	• It is unclear what priority should be given to these people? Priority to healthcare access, prevention, extensive evaluation, larger dose of treatment?
What and when to target to delay or halt the onset of OA after a traumatic knee injury		
C2a.	Efforts to delay or halt the onset of *symptomatic knee OA* after a traumatic knee injury should promote knee health through: i. Education[a] ii. Self-management[a] iii. Mitigating known modifiable risk factors for re-injury ad non-traumatic OA[a] iv. Person-centered goals[a]	• I can see all of these points as part of a broad strategy to facilitate self-management. • Is a patient-centered goal a goal that a patient has established themselves? Or a goal that is set with consideration for patient preference? I am not sure if a goal that a patient sets entirely themselves will prevent OA, but I do think it is the correct approach to treatment
C2b.	Efforts to delay or halt the onset of *symptomatic knee OA* after a traumatic knee injury should: i. Commence at the time of injury (as possible) ii. Continue across the lifespan	• The initial injury management period already has enough immediate priorities to add PTOA as an additional core focus. • 'Lifespan may be too vague'.
What to do after and ACL tear *The following are applicable to patients who have had an ACL tear and/or undergone an ACLR; but may not apply to every individual and situation. It is important that the patient and healthcare provider consider the unique features of a patient's injury, the resources available to them and their situation when developing a treatment plan.*		
C3a.	First-line treatment of an ACL tear includes: i. Education[a] ii. Exercise therapy-based rehabilitation (see C3c, d and e)	• Is education the best word? It implies that someone chooses the knowledge to push to the patient vs. the patient requesting information that is relevant = Informational Support
C3b.	The decision to undergo ACLR should be: i. Delayed at least until there is a 'quiet knee'[b] ii. Considered when a patient cannot achieve their acceptable functional level despite sufficient muscle function[a] iii. Made by the patient and informed by relevant stakeholders[a]	• What if a patient cannot achieve muscle function? What is sufficient muscle function? Is this a critical metric for surgical decision making? Are some patients unable to achieve sufficient muscle function due to pain or other symptoms relating to instability?

C3c.	ACL tear and ACLR rehabilitation should: i. Incorporate patient preferences ii. Be goal and/or criterion-based iii. Begin with supervised rehabilitation and profess through semi-supervised home(gym)-based rehabilitation to unsupervised home (gym) self-management	• What about periodic check-ups when transitioning to fully away from the clinic. Supervision at later stages is also important – is it a question about resources?
C3d.	Core components of ACL tear and ACLR rehabilitation include: i. Weight-bearing and ROM exercises[a] ii. Open and closed kinetic chain lower-limb resistance-based exercises[a] iii. Lower-limb neuromuscular control exercises[a] iv. Lower-limb plyometrics[a] v. Return to work, sport or other physical activity preparation[a] vi. Techniques to promote exercise adherence and self-management of knee health[a] vii. Cognitive behavioural techniques[c]	
C3e.	Adjunct treatments for ACL tear and ACLR rehabilitation to improve quadriceps strength can include: i. Neuromuscular electrical stimulation[a] ii. Blood-flow restriction training[a] iii. Whole-body vibration[a]	• Not convinced there is enough benefit to outweigh cost, therapist need, and discomfort
C3f.	ACL tear and ACLR rehabilitation does not include the following adjunct treatments: i. Continuous passive motion ii. Knee bracing	• There may be a time for bracing (e.g., unloader orthoses in the early post-ACL injury to improve weight bearing, placebo effect when doing demanding activities, lack of knee confidence, to progress rehabilitation, patient preference, to limit knee motion for patients with range of motion restrictions - meniscus repair). • Acknowledge that this recommendation could change over time with new evidence.
C3g.	After an ACL tear or ACLR, the following criteria should be achieved prior to returning to pivoting sports: i. At least 9-months post ACLR surgery ii. Pass a return to sport test battery[a]	• 9-month cut off is arbitrary and based on one study. I agree with the rationale for using a time cut. Not sure what the appropriate 'time' is.
What to monitor after a traumatic knee injury *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Choice of domain(s) will vary based on individual presentation, goals and practicality. Domains are listed in alphabetical order.*		
C4a.	Core domains to monitor after knee injury include i. knee-related adverse events[a] (including subsequent knee injury and giving way episodes ii. knee-related cognitive behavioural factors[a,c] iii. knee-related quality of life iv. knee-related pain v. knee-related symptoms other than pain[a] vi. physical activity and sport participation[a] vii. physical function (including self-reported function, functional performance and/or muscle function)	• Does it have to be "knee-related" or can it be broad cognitive behavioural factors?

	Additional domains that *may* be important for clinicians to monitor after knee injury include:	
C4b.	i. body weight	• Monitor weight on a case-by-case basis depending on and in consultation with the patient. • Weight management may be appropriate, but clinically calculating BMI is time consuming. • BMI is not as meaningful as body weight to a patient. • Focusing on PA and nutrition is probably more effective than focusing on weight.
	ii. health-related quality of life (including physical and mental aspects)	
	iii. mental health[a]	• It might be appropriate to screen for mental health issues but not to monitor ongoing. • Mental health monitoring requires a specific skill set and requires consultation with qualified healthcare professional vs. a physiotherapist. • I don' agree with monitoring or measuring continuously. • How is mental health different from mental aspects of QOL?
	iv. participation in social roles, responsibilities and relationships including occupation, care-giving and community participation[a]	• It might be appropriate to screen but not to monitor in an ongoing fashion.
C4c.	After knee injury, diagnostic imaging is only used if it will inform treatment planning	
	How to Monitor: Patient Reported Outcomes *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Recommended domains can be measured with instruments that measure **multiple domains** or **individual domains.** The instrument choice within each category will vary based on individual presentation, goals, practicality, and instrument availability. Domains and instruments are listed in alphabetical order.*	
C5a.	Recommended methods to monitor **multiple domains** after knee injury include: • IKDC-SKF[d] • KOOS[e] • Western Ontario Meniscal Evaluation Tool (WOMET)[f]	• Freely available multi-domain instruments are the best value for the clinic (time and resource restraints)
C5b.	Recommended methods to monitor **single domains** after knee injury include:	
	i. cognitive behavioural factors: • ACL Return to Sport after Injury scale (ACL-RSI, ACL Tear only) • Knee Self Efficacy Scale (K-SES) • Tampa Scale of Kinesiophobia (TSK-17 or TSK-11)	• TSK17/11 may not assess fear of reinjury/reinjury anxiety but I guess the best out there? • The recommendations offer guidance on which domain(s) to evaluate, but not which specific PROM is best to use within each domain
	ii. knee-related pain: • Numerical Rating Scale (NRS) • Visual Analogue Scale (VAS)	
	iii. knee-related quality of life: • ACL QOL score (ACL Tear only)	
	iv. health-related quality of life: • VAS: At this moment, how good or bad is your general/overall health? (0-the worst health you can imagine, 10-the best health you can imagine) • SF-12[g]	• Why is EQ-5D-5L not included
	v. mental health[e] • See supplementary file for examples[a]	
	vi. participation in social roles, responsibilities and relationships (including occupation, care-giving and community participation) • See supplementary file for examples[a]	
	vii. Physical activity and sport participation • Physical Activity resumption and frequency[a] • Sport Participation type[a]	

How to Monitor: Muscle Function[h] *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Tests should only be performed when it is safe to do so. Method choice may be influenced by individual presentation, goals, practicality, and availability of instruments. Methods are listed in alphabetical order.*		
C6a.	Recommended clinical measures of knee muscle function[h] after knee injury are peak knee extensor and flexor strength.	• It is important to state whether this is something all should do, or only those that have the time and equipment for it. Obviously, muscle strength is important, but not all would have a dynamometer, so if it is something we consider a core outcome, then we need to accept that people do it with a weight machine although the other measures might be better.
C6b.	Recommended methods to estimate peak knee extensor and flexor strength in clinical settings include:	• Consider indicating that this list is a gradient from best/most accurate to least accurate - dynamometer > HHD > weight machine. Clinicians should understand and acknowledge the uncertainty and imprecision when making clinical decisions.
	i. computerised Dynamometry: concentric isokinetic contraction at ≥60°/s	• Based on availability – appropriate if available/access • Isokinetic testing at ≥180°/s is less reliable and can be quite uncomfortable for patients
	ii. Hand-held dynamometry[i,j]: isometric 1RM	• Include caveat on measurement position/set up are needed for quad • 1 RM can be estimated sub maximally, and may be most appropriate in acute situations
	iii. weight machine (e.g., knee extension or prone leg curl): concentric isotonic 1RM[j]	• I like 3 or 5 RM for weight machine for knee extension or hamstring curl. I find this to be better for the patient. Might suggest adding a one line here of 1, 3, or 5 RM.
C6c.	Recommended additional clinical measures of knee muscle function[h] that are important to monitor after knee injury include:	• Is there a hierarchy implied here, e.g., endurance is more important than power or vice versa? Is one more important than the other?
	i. knee extensor and flexor endurance	• Provide examples on how to do assess power and endurance otherwise leave out. Typically, power and endurance highly correlate with strength anyway.
	ii. knee extensor and flexor power	• I question the clinical feasibility of muscle power tests (e.g., rate of force development)
C6d.	Recommended other muscle groups to monitor after knee injury include those in the lower leg, hip and trunk.	• It is important to keep monitoring the most important muscles (i.e., knee extensors/flexors).
How to Monitor: Functional Performance[k] *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Tests should only be performed when it is safe to do so. Method choice may be influenced by individual presentation, goals, practicality, and availability of instruments. Methods are listed in alphabetical order.*		
C7a.	Recommended clinical measures of functional performance[k] after a knee injury are hop performance.	• What if a hop is not a meaningful function for the patient? • Clinically, hopping is less important than peak strength, and power and endurance in functional tasks
C7b.	Recommended methods to estimate hop performance in clinical settings include:	
	i. a battery of hop tests (e.g., more than one test)	• All directions of hop may be appropriate but not feasible in a general clinical setting. • Clarify that this recommendation is based on a combination of tests, rather than recommending all are completed with each patient
	ii. the hop battery should include tests that assess forward (single and repeated), diagonal and/or vertical hopping	• Do we know enough to recommend all hop directions - as it increases testing burden? • Should be specific to the patient's needs and intended activity/sport demands. • Is there a hierarchy implied in the order?
C7c.	Recommended hop tests for use after knee injury include[l]:	
	i. Diagonal hop = Crossover Hop Test (CH)[m]	
	ii. Single forward hop = Single Hop Test (SLH)[m]	
	iii. Repeated forward hop = Triple Hop Test (TH)[m]	
	iv. Vertical hop = Vertical Hop Test (VH)[m]	
	v. Repeated forward hop = 6-meter Timed Hop Test (6mTH)[m]	• Caution for responsiveness (insufficient but low evidence)
C7d.	Recommended additional clinical measures of functional performance that are important to monitor after knee injury include balance, agility or other task meaningful to the patient.[a]	• This is really broad • For balance, consider dynamic balance, which has more use in sport setting. • Should we also recommend monitor performance of tasks under fatigue?

Interpreting Patient Reported, Muscle Function and Functional Performance Outcome Domain Status and Change	
C8a.	To interpret a change in an outcome domain after knee injury, ask the patient if they have noticed a meaningful change in the domain. *Example: 'Have you noticed a meaningful change in your knee pain, over the last 6 weeks?'*
C8b.	To assess the current state of an outcome domain after knee injury, ask the patient if they feel their current state is acceptable/satisfactory. *For example: 'Taking into consideration all you do in a typical day, is the current state of your hop performance satisfactory?*
C8c.	To better understand a patient's experience of an outcome domain after a knee injury, ask them about individual PROM item responses. *Example (KOOS Q3): 'You indicate you are severely troubled by a lack of knee confidence, can you tell me a bit more about that? In what situations do you feel confident or lack confidence in your knee?'*
C8d.	To document an outcome domain for a health record or report, include the following information: i. The baseline and follow-up score, and any change (either improvement or deterioration) in the outcome *Example: insert name had a 15% improvement in knee extensor strength over 4 weeks, (baseline scores = 25 lbs, follow-up score = 29 lbs* ii. If the patient felt the change in the outcome was meaningful *Example: insert name felt that the increase was meaningful* iii. If the person feels that their current state of an outcome is acceptable/satisfactory. *Example: insert name reports that after taking into account all they have to do in a typical day, the current state of their knee extensor strength is satisfactory.*

7. Research Recommendations: Summary of Evidence and Appropriateness Rating

Table 5. Research Recommendations: Summary of Evidence and Appropriateness Rating

	Research Recommendation	Evidence	Median	Min-Max	Mode	Appropriateness	Votes
Overarching priorities for post-traumatic knee OA research							
R1a.	Prioritize ***symptomatic*** definitions of post-traumatic knee OA (consensus-based clinical signs and symptoms with or without the presence of structural features) over ***structural*** definitions.	Expert Opinion	9	5-9	9	Appropriate	32
R1b.	Reach consensus on how to define, measure and report ***symptomatic and structural*** post-traumatic knee OA to facilitate data synthesis and meta-analysis (including individual participant data meta-analyses).	Expert Opinion	9	7-9	9	Appropriate	32
R1c.	Investigate the influence of sex, gender, race, and other social determinants of health on the development of post-traumatic knee OA to understand disparities across populations.	Expert Opinion	8	4-9	9	Appropriate	32
Study Design: Risk factors for OA after traumatic knee injury							
R2a.	Consider ACL tear and non-ACL tear related injuries when investigating risk factors for ***symptomatic*** post-traumatic knee OA.	Expert Opinion	9	5-9	9	Appropriate	32
R2b.	Report ***structural*** knee OA by overall knee joint and individual joint compartment (i.e., medial tibiofemoral, lateral tibiofemoral and patellofemoral).	Expert Opinion	9	5-9	9	Appropriate	32
Study Design: Interventions after traumatic knee injury							
R2c.	Clinical trials of rehabilitation interventions with follow-up beyond 5 years would provide a better understanding if interventions can reduce the risk of ***symptomatic*** and ***structural OA*** after knee injury.	Expert Opinion	9	8-9	9	Appropriate	34
R2d.	Evaluate the effectiveness (clinical trial) of different management strategies (including rehabilitation interventions) in participants with ACL deficiency, isolated meniscal tears, an/or non-ACL tear knee injuries.	Expert Opinion	9	5-9	9	Appropriate	34
Study Design: Outcome domains after a traumatic knee injury *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated.* *Choice of domain(s) will vary based on the research question. Domains are listed in alphabetical order.*							
R3a.	Core domains to monitor in intervention and observational studies of persons following a knee injury include	Expert Opinion[11 12]					
	i. knee-related adverse events[a] (including subsequent knee injury and giving way episodes		9	7-9	9	Appropriate	31
	ii. knee-related cognitive behavioural factors[a,b]		9	5-9	9	Appropriate	31
	iii. knee-related quality of life		9	7-9	9	Appropriate	31
	iv. knee-related pain		9	5-9	9	Appropriate	31
	v. knee-related symptoms other than pain[a]		9	5-9	9	Appropriate	31
	vi. patient global assessment[a]		9	5-9	9	Appropriate	31
	vii. physical activity and sport participation[a]		9	7-9	9	Appropriate	31
	viii. physical function (including self-reported function, functional performance and/or muscle function)		9	6-9	9	Appropriate	31

R3b.	Depending on the research question, it may also be important to assess: i. body mass index and adiposity ii. comorbidities iii. health-related quality of life (including physical and mental aspects) iv. injury-related costs (direct and indirect) v. mental health[a] vi. molecular and imaging biomarkers vii. participation in social roles, responsibilities and relationships including occupation, care-giving and community participation[a]	Expert consensus[11] Expert opinion[6 13 14]	9 8 9 9 8 8 8	3-9 6-9 5-9 5-9 4-9 2-9 6-9	9 9 9 9 9 9 9	Appropriate Appropriate Appropriate Appropriate Appropriate Appropriate Appropriate	31 31 31 31 31 31 31
R3c.	Consider monitoring individuals at elevated risk of ***symptomatic*** post-traumatic knee OA across the entire timespan from injury to any OA diagnosis.	Expert opinion[2 12]	9	6-9	9	Appropriate	31
	How to Monitor: Patient Reported Outcomes *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. PROM choice may be influenced by individual research questions. Domains and instruments are listed in alphabetical order.*						
R4a.	Recommended options to monitor **core domains** after knee injury to facilitate data synthesis include: i. knee-related cognitive behavioural factors: • ACL Return to Sport after Injury scale (ACL-RSI, ACL Tear only) • Knee Self Efficacy Scale (K-SES) • Tampa Scale of Kinesiophobia (TSK-17 or TSK-11) ii. knee-related pain: • KOOS Pain subscale ($KOOS_{Pain}$) • Numerical Rating Scale (NRS) • Visual Analogue Scale (VAS) iii. knee-related physical function: • KOOS Function in Sport and Recreation subscale ($KOOS_{Sport/Rec}$) iv. knee-related quality of life: • ACL QOL score (ACL Tear only) • KOOS QOL subscale v. knee-related SYMPTOMS other than pain: • KOOS Symptoms subscale ($KOOS_{Symptoms}$) vi. patient global assessment: • Global Rate of Change Score (GROC) • Patient Acceptable Symptom State (PASS) • Treatment Failure (TF) vii. physical activity and sport participation: • Physical Activity resumption and frequency[a] • Sport Participation type[a]	ACL-RSI (COSMIN 6/8) [12] K-SES (Expert Opinion) TSK-17, TSK-11 (Expert Opinion) $KOOS_{Pain}$ (COSMIN 2/8)[12] NRS (Expert Opinion) VAS (Expert Opinion) $KOOS_{Sport/Rec}$ (COSMIN 2/8)[12] ACL QOL (COSMIN 3/8)[12] $KOOS_{QOL}$ (COSMIN 2/8)[12] $KOOS_{Symptoms}$ (COSMIN 2/8)[12] GROC[22] (Expert Opinion)[25] PASS[23] TF[26] Expert Opinion [17]	8 9 9 9 9 9 9	6-9 7-9 6-9 7-9 5-9 5-9 6-9	9 9 9 9 9 9 9	Appropriate Appropriate Appropriate Appropriate Appropriate Appropriate Appropriate	31 31 31 31 31 31 31

R4b.	Recommended methods to monitoring **additional domains** after knee injury to facilitate data synthesis include: i. health-related quality of life: • EQ-5D Index[c] • SF-12 or SF-36[c]	Expert opinion[13]	9	6-9	9	Appropriate	31
	ii. mental health: • Methods used to assess these constructs will depend upon the research question and study population[a]	Expert Opinion[16]	8	5-9	9	Appropriate	31
	iii. participation in social roles, responsibilities and relationships (including occupation, care-giving and community participation): • Methods used to assess these constructs will depend upon the research question and study population[a]	Expert Opinion	8	5-9	9	Appropriate	31
	iv. multiple domains after knee injury: • IKDC-SKF[d] • Western Ontario Meniscal Evaluation Tool[e]	ACL Tear: • IKDC-SKF (COSMIN 3/8)[12] Meniscus Tear: • IKDC-SKF (COSMIN 2/8)[15] • WOMET (COSMIN 4/8)[15]	9	1-9	9	Appropriate	31
How to Monitor: Muscle Function[f]							
Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Method choice may be influenced by individual research questions.							
R5a.	The best available measures of muscle function after knee injury are peak knee extensor and flexor strength.	Expert Opinion[18 19]	9	5-9	9	Appropriate	33
R5b.	Recommended methods to estimate peak knee extensor and flexor strength in research settings (in order of most to least scientific rigor) include; i. computerised dynamometry: concentric isokinetic contraction at ≥60°/s	Extensor GRADE[18]: • + Very low (Intra-RR) • + Moderate (Construct validity) Flexor GRADE[18]: • + Very low (Intra-RR) • - Moderate (Construct validity)	9	4-9	9	Appropriate	33
	ii. hand-held dynamometry[g]: isometric 1RM[h]	Extensor GRADE[18]: • + Moderate (Intra-RR) • - Very low (Inter-RR) • - High (Criterion validity) • -High (Construct validity)	7	1-9	7	Appropriate	33
	iii. weight machine (e.g., knee extension or prone leg curl): concentric isotonic 1RM[h]	Extensor/Flexor GRADE[18]: • + High (Criterion validity)	7	4-9	7	Appropriate	33
R5c.	Recommended additional measures of knee muscle function[h] that are important to monitor after knee injury include: i. knee extensor and flexor power[a]	Expert Opinion[19]	8	4-9	9	Appropriate	33
	ii. knee extensor and flexor endurance[a]		8	3-9	9	Appropriate	33
	iii. knee extensor and flexor morphology[a]		7	4-9	7	Appropriate	33
	iv. knee extensor and flexor neurophysiology[a]		7	4-9	9	Appropriate	33

R5d.	Recommended other muscle groups to monitor after knee injury include those in the lower leg, hip and trunk. • See supplementary file for examples[a]	Expert Opinion	8	4-9	9	Appropriate	33

How to Monitor: Functional Performance[j] *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Method choice may be influenced by individual research questions. Methods are listed in alphabetical order.*							
R6a.	The best available measures of functional performance[i] after a knee injury are hop performance tests.	Expert Opinion[20]	9	4-9	9	Appropriate	33
R6b.	Recommended methods to estimate hop performance in a research setting include: i. a battery of hop tests (e.g., more than one test)	Expert Opinion[20]	9	5-9	9	Appropriate	33
	ii. the hop battery should include tests that assess forward (single and repeated), diagonal and/or vertical hopping		9	5-9	9	Appropriate	33
R6c.	Recommended hop tests for use after knee injury include[j]: i. Diagonal hop = Crossover Hop Test (CH)[k]	CH GRADE[21]: • + Moderate (Intra-RR) • + Moderate (Construct validity) • + Low (Responsiveness)	9	4-9	9	Appropriate	33
	ii. Single forward hop = Single Hop Test (SLH)[k]	SLH GRADE[21]: • + High (Intra-RR) • + Low (Construct validity) • + Low (Responsiveness)	9	5-9	9	Appropriate	33
	iii. Repeated forward hop = Triple Hop Test (TH)[k]	TH GRADE[21]: • + Very low (Intra-RR) • + Moderate (Construct validity) • - Low (Responsiveness)	9	4-9	9	Appropriate	33
	iv. Vertical hop = Vertical Hop Test (VH)[k]	VH GRADE[21]: • + Moderate (Intra-RR) • + Moderate (Construct validity)	9	5-9	9	Appropriate	33
	v. Repeated forward hop = 6-meter Timed Hop Test (6mTH)[k]	6mTH GRADE[21]: • + Moderate (Intra-RR) • + Low (Construct validity) • - Insufficient (Responsiveness)	8	4-9	9	Appropriate	33
R6d.	Recommended additional measures of functional performance that are important to monitor after knee injury include balance, agility or other task meaningful to the participant.[a]	Expert Opinion	8	4-9	9	Appropriate	33

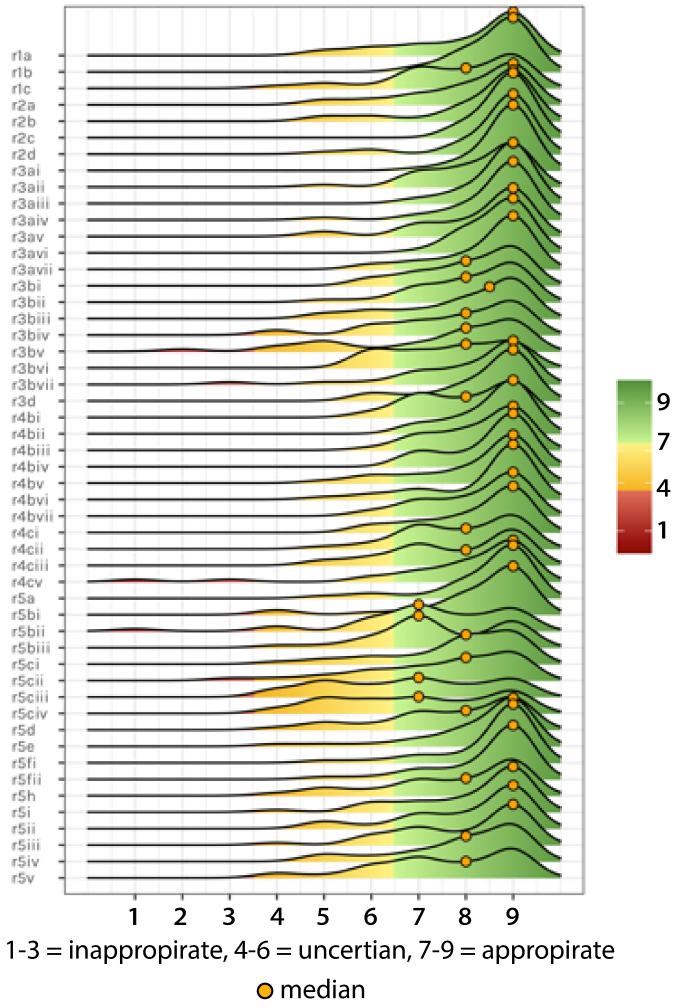
Interpreting Patient Reported, Muscle Function and Functional Performance Outcome Domain Status and Change
• Information to assist in the interpretation of PROMs', muscle strength and hop performance can be found in the supplementary file 4. The information was **not voted on.**

[a]See attached supplementary file for examples (examples were not be voted on)
[b]Characteristics of a person that affect performance and learning
[c]Licencing requirements apply but may be available through your employer
[d]Assesses knee-related symptoms, sports activities, function and activities of daily living
[e]Assesses knee-related physical symptoms, sports, recreation, work, lifestyle, emotions
[f]Muscle function refers to the capacity of a muscle to do work. Muscle function can be measured as strength, power, or endurance.
[g]HHD assessment of isometric knee extensor and flexor strength can underestimate strength. To obtain the most precise estimate it is important to secure the femur, have the patient push into resistance generated by a fixed belt (not the assessor hand), and for re-assessment to be conducted by the same assessor. Isometric scores are not interchangeable with isokinetic or isotonic scores.
[h]Estimates of 1RM should be based on the average of at least two *repeated* measures of maximum effort.
[i]Functional performance is the action of carrying out or accomplishing a movement, movement task or movement activity
[j]Insufficient evidence to inform the 'best' test or 'best' order
[k]See supplementary file for test description

+ (sufficient measurement property), - (insufficient measurement property) as per the COSMIN, 1 RM (1 repetition maximum), ACL (Anterior Cruciate Ligament), ACLR (ACL reconstruction), GRADE (Grading of Recommendations, Assessment, Development and Evaluations), Dynamometry), OA (osteoarthritis), PROM (patient reported outcome measure), ROM (range of motion), RR (Rater Reliability)

Whittaker JL, *et al. Br J Sports Med* 2022;0:1–13. doi: 10.1136/bjsports-2022-106299

8. Research Recommendations: Voting Distribution



9. Research Recommendations: Dissenting Viewpoints

Table 6. Research Recommendations: Dissenting Viewpoints

	Research Recommendation	Comments and Dissenting Viewpoint
R1a.	Prioritize ***symptomatic*** definitions of post-traumatic knee OA (consensus-based clinical signs and symptoms with or without the presence of structural features) over ***structural*** definitions.	• Structural definitions of OA are probably very relevant for research on mechanisms, biology etc. • Defining symptomatic OA as present or absent is useful for defining inclusion criteria, or for incidence of symptomatic OA as a dichotomous outcome. But measuring changes in this will be very hard (e.g., for epidemiology studies) due to the highly varied nature of pain.
R1b.	Reach consensus on how to define, measure and report ***symptomatic and structural*** post-traumatic knee OA to facilitate data synthesis and meta-analysis (including individual patient data meta-analyses).	
R1c.	Investigate the influence of sex, gender, race, and other social determinants of health on the development of post-traumatic knee OA to understand disparities across populations.	
Study Design: Risk factors for OA after traumatic knee injury		
R2a.	Consider ACL tear and non-ACL tear related injuries when investigating risk factors for ***symptomatic*** post-traumatic knee OA.	• Other knee injuries should be taken into account, as single-structure or multi-structure injuries are also considered risk factors for OA development.
R2b.	Report ***structural*** knee OA by overall knee joint and individual joint compartment (i.e., medial tibiofemoral, lateral tibiofemoral and patellofemoral).	
Study Design: Interventions after traumatic knee injury		
R2c.	Clinical trials of rehabilitation interventions with follow-up beyond 5 years would provide a better understanding if interventions can reduce the risk of ***symptomatic*** and ***structural OA*** after knee injury	
R2d.	Evaluate the effectiveness (clinical trial) of different management strategies (including rehabilitation interventions) in patients with ACL deficiency, isolated meniscal tears, an/or non-ACL tear knee injuries.	
Study Design: Outcome domains after a traumatic knee injury *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated.* *Choice of domain(s) will vary based on the research question. Domains are listed in alphabetical order.*		
R3a.	Core domains to monitor in intervention and observational studies of persons following a knee injury include	
	i. knee-related adverse events[a] (including subsequent knee injury and giving way episodes	• The outcome depends on the specific research question more than the population being evaluated.
	ii. knee-related cognitive behavioural factors[a,b]	
	iii. knee-related quality of life	
	iv. knee-related pain	
	v. knee-related symptoms other than pain[a]	• I am not convinced we have good enough tools to evaluate "other symptoms". KOOS Symptoms is an option, but I am not convinced of psychometric properties. It is not clear to me what symptoms would be important to include as core item domains, other than pain and instability - giving way (already captured in adverse events).
	vi. patient global assessment[a]	• I am not sure the global assessment questions are very important to include as core domains in research studies.
	vii. physical activity and sport participation[a]	
	viii. physical function (including self-reported function, functional performance and/or muscle function)	

R3b.	Depending on the research question, it may also be important to assess: i. body mass index and adiposity	• BMI should be moved up to core domain, while other measures of adiposity are optional.
	ii. comorbidities	
	iii. health-related quality of life (including physical and mental aspects)	• it is not clear what the distinction is between mental health and mental aspects of QOL, but agree that it may be important to evaluate mental health.
	iv. injury-related costs (direct and indirect)	
	v. mental health[a]	
	vi. molecular and imaging biomarkers	• Only relevant for specific research questions.
	vii. participation in social roles, responsibilities and relationships including occupation, care-giving and community participation[a]	
R3d.	Consider monitoring individuals at elevated risk of ***symptomatic*** post-traumatic knee OA across the entire timespan from injury to any OA diagnosis.	• Monitor beyond OA diagnosis as well? • It's not clear to me if the focus is that: individuals should be at risk of symptomatic knee PTOA, people should be monitored at all time points following injury, or studies should have a lifelong follow-up time?
	How to Monitor: Patient Reported Outcomes *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. PROM choice may be influenced by individual research questions.* *Domains and instruments are listed in alphabetical order.*	
R4a.	Recommended options to monitor **core domains** after knee injury to facilitate data synthesis include: i. knee-related cognitive behavioural factors: • ACL Return to Sport after Injury scale (ACL-RSI, ACL Tear only) • Knee Self Efficacy Scale (K-SES) • Tampa Scale of Kinesiophobia (TSK-17 or TSK-11)	• TSK17/11 not the best tool for fear of reinjury/reinjury anxiety but I guess the best out there • Not as much known about these PROMs- less confident.
	ii. knee-related pain: • KOOS Pain subscale ($KOOS_{Pain}$) • Numerical Rating Scale (NRS) • Visual Analogue Scale (VAS)	
	iii. knee-related physical function: • KOOS Function in Sport and Recreation subscale ($KOOS_{Sport/Rec}$)	
	iv. knee-related quality of life: • ACL QOL score (ACL Tear only) • KOOS QOL subscale	
	v. knee-related SYMPTOMS other than pain: • KOOS Symptoms subscale ($KOOS_{Symptoms}$)	• Agree that assessing symptoms is important, but I am worried whether the KOOS Symptoms scale has good enough measurement properties.
	vi. patient global assessment: • Global Rate of Change Score (GROC) • Patient Acceptable Symptom State (PASS) • Treatment Failure (TF)	• Consider re-phrasing patient 'global assessment' to patient 'global status'
	vii. physical activity and sport participation: • Physical Activity resumption and frequency[a] • Sport Participation type[a]	

R4b.	Recommended methods to monitoring **additional domains** after knee injury to facilitate data synthesis include: i. health-related quality of life: • EQ-5D Index[c] • SF-12 or SF-36[c] ii. mental health: • Methods used to assess these constructs will depend upon the research question and study population[a] iii. participation in social roles, responsibilities and relationships (including occupation, care-giving and community participation): • Methods used to assess these constructs will depend upon the research question and study population[a]	
	iv. multiple domains after knee injury: • IKDC-SKF[d] • Western Ontario Meniscal Evaluation Tool[e]	• Unclear why single domain subscales (e.g., KOOS QOL, Pain) are included in research recommendations, but not as single domain options for clinical recommendations • Include the KOOS as a multiple domain instrument using KOOS4 as the outcome • Multiple domains evaluated by an aggregate score cannot be used for data synthesis across studies/instruments since it is unclear what construct(s) the multi-domain instrument assess.
How to Monitor: Muscle Function[f]		
Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Method choice may be influenced by individual research questions.		
R5a.	The best available measures of muscle function after knee injury are peak knee extensor and flexor strength.	
R5b.	Recommended methods to estimate peak knee extensor and flexor strength in research settings (in order of most to least scientific rigor) include; i. Computerised Dynamometry: concentric isokinetic contraction at ≥60°/s	• All are acceptable depending on the question being asked, but computerized dynamometry should be the standard if measuring muscle function in this population, regardless of the question. • Isokinetic testing at ≥180°/s is less reliable and can be quite uncomfortable for patients
	ii. HHD[g]: isometric 1RM[h]	• Include caveat about methods
	iii. Weight machine (e.g., knee extension or prone leg curl): concentric isotonic 1RM[h]	
R5c.	Recommended additional clinical measures of knee muscle function[h] that are important to monitor after knee injury include: i. knee extensor and flexor power[a]	• Is there a hierarchy implied here, e.g., endurance is more important than power or vice versa? Is one more important than the other?
	ii. knee extensor and flexor endurance[a]	
	iii. knee extensor and flexor morphology[a]	• Need more information regarding "morphology" and "neurophysiology" to be able to vote on • Morphology and Neurophysiology are not that important to monitor
	iv. knee extensor and flexor neurophysiology[a]	
R5d.	Recommended other muscle groups to monitor after knee injury include those in the lower leg, hip and trunk. • See supplementary file for examples[a]	

How to Monitor: Functional Performance[j] *Recommendations apply to any traumatic knee injury and/or associated surgery unless otherwise indicated. Method choice may be influenced by individual research questions. Methods are listed in alphabetical order.*		
R6a.	The best available measures of functional performance[i] after a knee injury are hop performance tests.	• What if a hop is not a meaningful for the patient?
R6b	Recommended methods to estimate hop performance in a research setting include: i. a battery of hop tests (e.g., more than one test) ii. the hop battery should include tests that assess forward (single and repeated), diagonal and/or vertical hopping	
R6c.	Recommended hop tests for use after knee injury include[i]: i. Diagonal hop = Crossover Hop Test (CH)[k] ii. Single forward hop = Single Hop Test (SLH)[k] iii. Repeated forward hop = Triple Hop Test (TH)[k] iv. Vertical hop = Vertical Hop Test (VH)[k] v. Repeated forward hop = 6-meter Timed Hop Test (6mTH)[k]	• Caution for responsiveness (insufficient but low evidence)
R6d.	Recommended additional clinical measures of functional performance that are important to monitor after knee injury include balance, agility or other task meaningful to the patient.[a]	• How do we incorporate "other task meaningful to the patient" in a research setting?
Interpreting Patient Reported, Muscle Function and Functional Performance Outcome Domain Status and Change		
Information to assist in the interpretation of PROMs', muscle strength and hop performance can be found in the supplementary file. The information in the table was **not voted on.**		

REFERENCES

1. Whittaker JL, Losciale JM, Juhl CB, et al. Risk factors for knee osteoarthritis after knee trauma: a systematic review and meta-analysis of randomised controlled trials and cohort studies for the OPTIKNEE consensus. *Br J Sports Med* Under Review
2. Whittaker JL, Runhaar J, Bierma-Zeinstra S, et al. A lifespan approach to osteoarthritis prevention. *Osteoarthritis Cartilage* 2021;29(12):1638-53. doi: 10.1016/j.joca.2021.06.015 [published Online First: 2021/09/25]
3. Filbay SR, Grindem H. Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture. *Best Pract Res Clin Rheumatol* 2019;33(1):33-47. doi: 10.1016/j.berh.2019.01.018 [published Online First: 2019/08/23]
4. Culvenor AG, Girdwood MA, Juhl CB, et al. Rehabilitation after anterior cruciate ligament and meniscal injuries: a best-evidence synthesis of systematic reviews for the OPTIKNEE consensus. *Br J Sports Med* 2022 doi: 10.1136/bjsports-2022-105495
5. Holm PM, Juhl C, Culvenor AG, et al. Effectiveness of initial management strategies and rehabilitation approaches to improve knee joint structural and biological outcomes after injury: a systematic review of ransomised controlled trials for the OPTIKNEE consensus. *Osteoarthritis & Cartilage* Under Review
6. Truong LK, Mosewich AD, Holt CJ, et al. Psychological, social and contextual factors across recovery stages following a sport-related knee injury: a scoping review. *Br J Sports Med* 2020;54(19):1149-56. doi: 10.1136/bjsports-2019-101206 [published Online First: 2020/02/16]
7. van Melick N, van Cingel RE, Brooijmans F, et al. Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus. *Br J Sports Med* 2016;50(24):1506-15. doi: 10.1136/bjsports-2015-095898 [published Online First: 2016/08/20]
8. Andrade R, Pereira R, van Cingel R, et al. How should clinicians rehabilitate patients after ACL reconstruction? A systematic review of clinical practice guidelines (CPGs) with a focus on quality appraisal (AGREE II). *Br J Sports Med* 2020;54(9):512-19. doi: 10.1136/bjsports-2018-100310 [published Online First: 2019/06/09]
9. Webster KE, Hewett TE. What is the Evidence for and Validity of Return-to-Sport Testing after Anterior Cruciate Ligament Reconstruction Surgery? A Systematic Review and Meta-Analysis. *Sports medicine* 2019;49(6):917-29. doi: 10.1007/s40279-019-01093-x
10. Meade LB, Bearne LM, Sweeney LH, et al. Behaviour change techniques associated with adherence to prescribed exercise in patients with persistent musculoskeletal pain: Systematic review. *Br J Health Psychol* 2019;24(1):10-30. doi: 10.1111/bjhp.12324 [published Online First: 2018/06/19]
11. Smith TO, Hawker GA, Hunter DJ, et al. The OMERACT-OARSI Core Domain Set for Measurement in Clinical Trials of Hip and/or Knee Osteoarthritis. *J Rheumatol* 2019;46(8):981-89. doi: 10.3899/jrheum.181194 [published Online First: 2019/01/17]
12. Gagnier JJ, Shen Y, Huang H. Psychometric Properties of Patient-Reported Outcome Measures for Use in Patients with Anterior Cruciate Ligament Injuries: A Systematic Review. *JBJS Rev* 2018;6(4):e5. doi: 10.2106/JBJS.RVW.17.00114 [published Online First: 2018/04/11]
13. Filbay SR, Skou ST, Bullock GS, et al. The long-term burden of anterior cruciate ligament and meniscal injury: A systematic review and meta-analysis for the OPTIKNEE consensus. Under Review
14. Emery CA, Whittaker JL, Mahmoudian A, et al. Establishing outcome measures in early knee osteoarthritis. *Nature reviews Rheumatology* 2019;15(7):438-48. doi: 10.1038/s41584-019-0237-3 [published Online First: 2019/06/16]

15. Abram SGF, Middleton R, Beard DJ, et al. Patient-reported outcome measures for patients with meniscal tears: a systematic review of measurement properties and evaluation with the COSMIN checklist. *BMJ open* 2017;7(10):e017247. doi: 10.1136/bmjopen-2017-017247 [published Online First: 2017/10/17]
16. Kendrick T, El-Gohary M, Stuart B, et al. Routine use of patient reported outcome measures (PROMs) for improving treatment of common mental health disorders in adults. *Cochrane Database Syst Rev* 2016;7:CD011119. doi: 10.1002/14651858.CD011119.pub2 [published Online First: 2016/07/14]
17. Ardern CL, Glasgow P, Schneiders A, et al. 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. *Br J Sports Med* 2016;50(14):853-64. doi: 10.1136/bjsports-2016-096278 [published Online First: 2016/05/27]
18. Urhausen A, Berg B, Oiestad BE, et al. Measurement properties for muscle strength tests following anterior cruciate ligament or meniscal injury – where do we need to go and what tests to use? A systematic review of measurement properties for the OPTIKNEE initiative. *Br J Sports Med* Under Review
19. Tayfur B, Charuphongsa C, Morrissey D, et al. Neuromuscular Function of the Knee Joint Following Knee Injuries: Does It Ever Get Back to Normal? A Systematic Review with Meta-Analyses. *Sports medicine* 2021;51(2):321-38. doi: 10.1007/s40279-020-01386-6 [published Online First: 2020/11/29]
20. Logerstedt DS, Scalzitti D, Risberg MA, et al. Knee Stability and Movement Coordination Impairments: Knee Ligament Sprain Revision 2017. *J Orthop Sports Phys Ther* 2017;47(11):A1-A47. doi: 10.2519/jospt.2017.0303
21. Berg B, Urhausen AP, Oiestad BE, et al. What tests should be used to assess functional performance in youth and young adults following anterior cruciate ligament or meniscal injury? A systematic review of measurement properties for the OPTIKNEE consensus. *Br J Sports Med* 2022 doi: 10.1136/bjsports-2022-105510 [published Online First: 2022/06/14]
22. Ingelsrud LH, Terwee CB, Terluin B, et al. Meaningful Change Scores in the Knee Injury and Osteoarthritis Outcome Score in Patients Undergoing Anterior Cruciate Ligament Reconstruction. *Am J Sports Med* 2018;46(5):1120-28. doi: 10.1177/0363546518759543 [published Online First: 2018/03/09]
23. Tubach F, Ravaud P, Baron G, et al. Evaluation of clinically relevant states in patient reported outcomes in knee and hip osteoarthritis: the patient acceptable symptom state. *Ann Rheum Dis* 2005;64(1):34-37.
24. Failla MJ, Arundale AJ, Logerstedt DS, et al. Controversies in knee rehabilitation: anterior cruciate ligament injury. *Clin Sports Med* 2015;34(2):301-12. doi: 10.1016/j.csm.2014.12.008 [published Online First: 2015/03/31]
25. Macri EM, Young JJ, Ingelsrud LH, et al. Meaningful thresholds for patient-reported outcomes following interventions for anterior cruciate ligament tear or traumatic meniscus injury: an OPTIKNEE systematic review. *Br J Sports Med* Under Review
26. Barenius B, Forssblad M, Engström B, et al. Functional recovery after anterior cruciate ligament reconstruction, a study of health-related quality of life based on the Swedish National Knee Ligament Register. *Knee Surg Sports Traumatol Arthrosc* 2013;21(4):914-27.

SUPPLEMENTARY FILE 4: Example

1. **Examples to accompany the clinical and research recommendations**
2. **Guidance for interpreting changes in patient reported outcomes, muscle function and functional performance outcomes**

Whittaker JL, *et al. Br J Sports Med* 2022;0:1–13. doi: 10.1136/bjsports-2022-106299

1. Examples to accompany clinical and research recommendations

Table 1. Examples* to accompany clinical and research recommendations

*The table contains examples (not voted on) and is not meant to be an exclusive list

C1. WHO to target to prevent PTOA:

People with single and multi-structure injuries (particularly ACL tears, meniscal tears, intraarticular tibiofemoral fractures, and patellar dislocations with concomitant chondral lesions).

Prioritise people with symptoms and/or functional impairments that persist beyond usual recovery times, or with a subsequent injury.

People to prioritise for PTOA prevention:

- Unable to reach a patient acceptable symptom state
- Hop test limb symmetry index <90%[1]
- Quadriceps strength symmetry index <80%[2]
- Hamstring strength symmetry index <90%[1]
- Overweight or obese[3]
- ACL graft rupture or ACLR revision

C2. WHAT and WHEN to target to prevent PTOA after traumatic knee injury:

Promote knee health through education, self-management, mitigating known modifiable risk factors for re-injury and non-traumatic OA, and person-centred goals. Start these efforts at the time of injury (as possible) and continue across the lifespan.

Education topics[4-7]:

- Medium- and long-term impact of knee injuries on physical, mental and social health
- Benefits of exercise (including strength training) and physical activity
- Importance of preventing re-injury for OA prevention
- Benefits and risks associated with surgery (including ACLR), and when and how to decide to progress to surgery

Self-management topics[6 8]:

- Self-monitoring function
- Adjusting exercise prescription
- Pacing exercise and physical activity
- Overcoming pain/effusion flares
- Seeking healthcare support

Risk factors for re-injury and non-traumatic OA:

- Unhealthy bodyweight[3]
- Lower-limb muscle weakness, especially quadriceps strength[1 2]
- Physical inactivity[9]
- Female sex[10]
- Premature return to sport[11]

Features of patient centred goals[12]:

- Respect patients' values, preferences, expressed needs and available resources
- Set in collaboration with the patient
- Re-evaluated at regular intervals

Whittaker JL, *et al. Br J Sports Med* 2022;0:1–13. doi: 10.1136/bjsports-2022-106299

C3. WHAT TO DO after ACL tear:

First-line ACL tear treatment includes education and exercise-therapy-based rehabilitation. Delay the decision to undergo ACLR until there is a 'quiet knee'. The decision to have an ACLR should be made by the patient (informed by relevant stakeholders) if they cannot achieve their acceptable functional level despite sufficient muscle function.

ACL tear and ACLR rehabilitation incorporates patient preferences, is goal and/or criterion-based, and begins with supervised rehabilitation then semi-supervised home (gym)-based rehabilitation to unsupervised home (gym) self-management.

Core components of ACL tear and ACLR exercise-based rehabilitation include: Weight-bearing, mobility, open and closed kinetic chain resistance-based, neuromuscular control and plyometric lower-limb exercises (including neuromuscular electrical stimulation to improve quadriceps strength); return to work, sport or other physical activity preparation; techniques to promote exercise adherence and self-management of knee health^; and cognitive behavioural techniques as appropriate.

ACL tear and ACLR Rehabilitation DOES NOT include blood-flow restriction training, whole-body vibration, continuous passive motion, or knee bracing.

Return to pivoting sports criteria after ACL tear or ACLR include being at least 9-months post-ACL tear or ACLR **AND** passing a return to sport test battery.

Education topics:

- Information about the injury
- Potential for tissue healing (e.g., ACL tear healing)
- Recovery timeline
- Management approaches (e.g., rehabilitation and/or surgery)
- Importance of (lifelong) self-management
- Return to activity criteria
- Risk for PTOA

Quiet knee:

- Little to no joint effusion or pain, full passive and active tibiofemoral and patellofemoral range of motion, straight leg raise with little to no extension lag, and little to no limp with gait.[13]

Stakeholders:

- Orthopaedic surgeon
- Rehabilitation professional
- Family members
- Coach

Sufficient muscle function:

- Limb symmetry index ≥90% but still experiencing activity-related knee giving away

Supervised rehabilitation:

- Clinic or gym based
- Group class
- Digital (telerehab)

Exercise-based Rehabilitation:

- Weight bearing (e.g., walking, step up) and mobility (e.g., cycling, stretching) exercises
- Open (e.g., knee extension, hamstring curl), and closed chain (e.g., leg press, step down, squat) resistance-based exercises
- Open and closed chain lower limb neuromuscular control exercises (e.g., one leg balance, lunge)
- Open and closed chain lower limb plyometric exercises (e.g., jumping, hopping, pivoting, skipping)

Techniques for promoting exercise adherence and self-management[14]:

- Social support (therapeutic alliance)[15]
- Action planning and goal setting (e.g., SMART goals)[16]
- Instruction of behaviour followed by demonstration of behaviour
- Feedback on behaviour
- Practice/rehearsal

Cognitive behavioural techniques[17]:

- Relaxation
- Reframing injury and recovery
- Coping modelling
- Guided imagery
- Guided discovery of movements associated with fear
- Exposure to movements that are associated with a lack of confidence or fear
- Mindful movement

Return to sport test battery:

- >90% on the Knee Outcome Survey (Activities of Daily Living Scale), global rating scale of function, quadriceps symmetry AND hop test battery (crossover hop, single hop, triple hop and 6m timed hop) symmetry[11]

C4. WHAT TO MONITOR after a traumatic knee injury:

Core clinical outcomes include: knee-related pain, other symptoms, adverse events, cognitive behavioural factors that influence learning and performance, physical function (e.g., self-reported function, functional performance and/or muscle function), QOL, and physical activity and sport participation.

Other important clinical outcomes can include**:** body weight, health-related QOL, participation in social roles, responsibilities and relationships (e.g., occupation, care-giving community participation), and injury-related mental health (e.g., depression, anxiety).

Diagnostic imaging is only indicated when results will inform treatment planning.

Other symptoms:

- Stiffness
- Functional instability
- Functional limitations
- Locking
- Clicking or crepitus

Adverse events:

- Contra-lateral knee injury
- Subsequent injury
- ACL graft rupture
- Giving away
- Locking

Cognitive behavioural factors that influence learning and performance[8 18]:

- Fear (re-injury, giving out, locking)
- Anxiety (re-injury, giving out, locking)
- Frustration
- Knee confidence
- Knee self-efficacy
- Psychological readiness to return to sport

Physical activity and sport participation:

- Step count (commercial fitness tracker e.g., Fitbit©, iWatch©)
- Minutes of moderate intensity physical activity (commercial fitness tracker e.g., Fitbit©, iWatch©)
- Return to physical activities[19]
- Recreational activities or sport
- Return to competition
- Level of competition
- Restricted participation in a desired activity

C5. HOW TO MONITOR PATIENT-REPORTED OUTCOMES (PROs) after a traumatic knee injury:

Core clinical PROs to choose from to monitor MULTIPLE domains include:

- IKDC-SKF (composite score of knee-related symptoms, function and sports activities)
- KOOS (composite score AND single scores for knee pain, other symptoms, function in daily living, function in sport/recreation, QOL)
- WOMET (overall composite score of knee-related physical symptoms, sports/recreation/work/lifestyle, and emotions; meniscal injury only)

Other clinical PROs to choose from monitor SINGLE domains include:

- Pain: Numerical Rating Scale or Visual Analogue Scale
- Knee-related QOL: ACL QOL Score (ACL injury only)
- Health-related QOL: Visual Analogue Scale, or SF-12
- Knee-related cognitive behaviour factors: ACL-RSI Scale (ACL injury only), K-SES, or TSK-11
- Physical activity and sport participation: sport resumption and frequency
- Participation in social roles, responsibilities and relationships: occupation, care-giving and community
- Injury-related mental health: anxiety and depression

Health-related quality of life Visual Analogue Scale:

- At this moment how good or bad is your health? (0=the worst health you can imagine, 10=the best health you can imagine)

Physical activity and sport participation[19]:

- Since your knee injury have you attempted to do any recreational physical activity? (yes/no)
- Since your knee injury have you attempted training or competition in ANY sport? (no/yes-competition/yes-training only)
- Since your knee injury have you attempted training or competition in your MAIN pre-injury sport? (no/yes-at same or higher level/yes-at lower level, training only)
- Since your knee injury have you returned to your desired performance level? (no/yes)
- How many weeks in the last month have you done *(insert recommended number of minutes for your country)* minutes of moderate intensity physical activity?
- According to your commercial grade activity monitor (e.g., Fitbit©, iWatch©) what is your average weekly step count or minutes of exercise?

Participation in social roles, responsibilities and relationships:

- What (if any) social roles (e.g., committee leadership, coach, group membership, volunteer roles etc.), responsibilities (e.g., care provider, occupation etc.) and relationships (e.g., family role, friendships, mentor etc.) have been impacted by your knee injury?
- Which (if any) social roles, responsibilities and relationships are still impacted by your knee injury?

Injury-related mental health[20]:

- Depression
  - Patient Health Questionnaire 9 (PHQ-9)
  - Beck Depression Inventory (BDI) and BDI-II
  - Community Epidemiologic Survey Depression (CES-D) scale for DSM-III depression
  - Zung depression scale
  - Quick Inventory of Depressive Symptomatology (QIDS)
- Anxiety
  - Beck Anxiety Inventory (BAI)
  - General Anxiety Disorder Scale 7 (GAD-7)
- Depression and Anxiety
  - Hopkins's symptom checklist (SCL-90)
  - Hospital and Anxiety Scale (HADS)

C6. HOW TO MONITOR MUSCLE FUNCTION after a traumatic knee injury

Core clinical knee muscle function measures include: peak thigh muscle (knee extensor/flexor) strength.

Clinical measures of peak knee extensor/flexor strength include (as available):

- Computerized dynamometry (concentric isokinetic contraction at ≥60°/s)
- Hand-held dynamometry (isometric 1RM)
- Weight machine (concentric isotonic 1RM knee extension or knee flexor curl)

Other important clinical muscle function measures include: thigh muscle endurance and power, and trunk, hip and leg, muscle function.

Computerized Dynamometry (concentric isokinetic contraction ≥60°/s):

- see Undheim et al[21] for an example protocol

Hand-held Dynamometry (isometric 1RM):

- see Sinacore et al[22] for an example protocol

Weight machine (concentric isotonic 1RM):

- see Sinacore et al[22] for an example protocol
- see National Strength and Conditioning Assoication[23]

Knee extensor or Flexor Endurance:

- Number of knee extension against a set weight until fatigue
- Number of hamstring curls against a set weight until fatigue

Knee extensor or flexor Power:

- Standing Broad Jump[23]
- Vertical Jump[23]

Trunk Muscles:

- Trunk flexors
- Trunk extensors
- Trunk side flexors
- Trunk rotators

Hip Muscles:

- Hip flexors
- Hip extensors
- Hip side flexors
- Hip rotators

Leg Muscles:

- Ankle plantar flexors
- Ankle dorsiflexors
- Ankle evertors
- Ankle invertors
- Toe extensors
- Toe flexors
- Foot intrinsics

C7. HOW TO MONITOR FUNCTIONAL PERFORMANCE after a traumatic knee injury:

Core clinical measures of functional performance include: hopping

Clinical measures to estimate hop performance include: a battery of forward (single and repeated), diagonal and/or vertical hop tests.

Core clinical hop tests include:

- Crossover hop (diagonal)
- Single hop (single-forward)
- Triple-hop (ciii) and 6m timed hop (repeated-forward)
- Vertical hop (vertical)

Other important clinical measures of functional performance include: balance, agility or other tasks meaningful to the patient.

Crossover Hop Test:

- see Kyritsis et al[24] and Xergia et a[25]l for an example protocols

Single Hop Test:

- see Kyritsis et al[24] for an example protocol

Triple Hop Test:

- see Moksnes and Risberg[26] for an example protocol

6-meter Triple Hop Test:

- see Kise et al[27] for an example protocol

Vertical Hop Test:

- see Kotsifaki et al[28] for an example protocol

Balance tests:

- Y-balance test[29]
- STAR excursion balance test[30]

Agility tests:

- Shuttle run[31]
- T-ability test[24]
- Sprint test[32]
- Illinois agility test[32]
- Figure of 8 run[33 34]

Other meaningful functional tasks:

- Ascending or descending stairs or inclines
- Squatting
- Lunging
- Kneeling

C8. HOW TO INTERPRET PATIENT-REPORTED, MUSCLE FUNCTION, AND FUNCTIONAL PERFORMANCE outcome status and change:

To **interpret the change** and **current state** of an outcome, ask the patient if they have noticed a meaningful change in the domain, and if they feel their current state is acceptable/satisfactory. To better **understand a patient's experience** of an outcome domain after a knee injury ask about responses to individual PRO items.

Record the baseline and follow-up score, and direction of change (either improvement or deterioration) in the outcome, if the patient felt the change was meaningful, and if they feel that their current state of that outcome is acceptable/satisfactory.

To understand the current state, change and a patient's experience of an outcome domain:

- *'Have you noticed a meaningful change in your knee pain over the last 6 weeks?'*
- *'Taking into consideration all you do in a typical day, is the current state of your knee pain satisfactory?*
- *'You indicate you are severely troubled by a lack of knee confidence; can you tell me a bit more about that? In what situations do you feel confident or lack confidence in your knee?'*

To document an outcome domain in a health record or report:

- *Name had a 15% improvement in their maximal knee extensor strength over 4 weeks, (baseline scores = 25 lbs, follow-up score = 29 lbs)*
- *Name reports that after taking into account all they have to do in a typical day, the current state of their knee extensor strength is satisfactory.*

ACL (Anterior Cruciate Ligament), ACL-QOL (ACL Quality-of-Life Score), ACLR (ACL reconstruction), ACL-RSI (ACL Return to Sport after Injury scale), BMI (body mass index), EQ-5D (EuroQol 5 Dimensions), GROC (Global Rate of Change), HHD (Hand-held dynamometry), IKDC-SKF (International Knee Documentation Committee Subjective Knee Form), K-SES (Knee Self Efficacy Scale), KOOS (Knee injury and Osteoarthritis Outcome Score), Lbs (pounds), m (meter), NRS (Numerical Rating Scale), PASS (patient acceptable symptom state), PTOA (post-traumatic osteoarthritis), PROs (patient-reported outcome measures), QOL (quality-of-life), RM (repetition maximum), SF-12 (Short Form 12), SF-36 (Short Form 36), SMART (specific, measurable, attainable, relevant, timebound), TSK (Tampa Scale of Kinesiophobia), WOMET (Western Ontario Meniscal Evaluation Tool).

2. Guidance for interpreting changes in patient reported outcomes, muscle function and functional performance outcomes

The following table contains information that will assist interpreting changes in patient reported, muscle function and functional performance outcomes.

Considerations for Interpreting the Change Scores in Table 2:

- Patient reported outcome meaningful change scores:
  - Reflect what the average participant considers to be a threshold for a meaningful improvement and can guide the interpretation of outcome domains after knee injury.
  - Are based on the most conservative thresholds reported for persons who have had an ACL tear with or without a concomitant meniscal tear, or meniscal surgery, spanning gender and various timepoints post injury/surgery (6-24 months). As they are based on the most conservative threshold for what might be considered a severe intra-articular knee injury, they are less likely to lead to the interpretation that a change was meaningful when it was not, but may lead to missing a meaningful change when one has occurred.
  - Are likely to change as new knowledge becomes available.

- Muscle Strength outcome change scores:
  - Reflect variation or change in muscle strength scores that can guide interpretation of a true change (greater than measurement error) after knee injury.
  - Variation is based on reported coefficients of variation (standard deviation/mean).
  - Change is based on reported standard deviations of change (SDC=1.96*√2*Standard Error of Measurement).

- Hop Test outcome change scores:
  - Reflect limb symmetry index values that can guide interpretation of a true change (greater than measurement error) after knee injury.
  - Limited by the observation that limb symmetry index is influenced by changes in performance of both the injured and contralateral leg.

Whittaker JL, *et al. Br J Sports Med* 2022;0:1–13. doi: 10.1136/bjsports-2022-106299

Table 2. Guidance for interpreting changes in PROs, muscle function and hop performance

	Domain, Instrument and Meaningful Change Score	Evidence Level
Patient Reported Outcome	**Multiple domain** instruments change scores: • KOOS: see individual subscale change scores below • IKDC-SKF: change of 16/100 (ACL tear), 11/100 (meniscus tear) • WOMET: change of 15/100 (meniscus tear)	ACL Tear IKDC-SKF (Low credibility)[35 36] Meniscus Tear IKDC-SKF (Very low credibility)[35 37] WOMET (Expert opinion)[38 39]
	Knee-related pain instruments change scores: • $KOOS_{Pain}$: change of 12/100 • NRS and VAS: change of 1.5/10	$KOOS_{Pain}$ (Low credibility)[35] NRS (Expert opinion)[40] VAS (Expert opinion)[40]
	Knee-related other symptoms instruments change scores: • $KOOS_{Symptoms}$: change of 6/100 (ACL tear), 12/100 (meniscus surgery)	$KOOS_{Symptoms}$ (Low credibility)[35]
	Knee-related physical function instrument change scores: • $KOOS_{Sport/Rec}$: change of 22/100 (ACL tear), 17/100 (meniscus tear)	ACL Tear IKDC-SKF (Low credibility)[35 36] $KOOS_{Sport/Rec}$ (Low credibility)[35 41] Meniscus Tear IKDC-SKF (Very low credibility)[35 37]
	Knee-related quality of life instruments change scores: • ACL QOL: change of 9/100 • $KOOS_{QOL}$: change of 18/100 (ACL tear), 17/100 (meniscus tear)	ACL Tear ACL QOL (Very low credibility) [42] $KOOS_{QOL}$ (High credibility)[35 41] Meniscus Tear $KOOS_{QOL}$ (Low credibility)[2, 17]
	Knee-related cognitive behavioural factor instruments change scores: • ACL RSI: change of 3/100 • K-SES: change of 15/100 • TSK-17: change of 1/68 (ACL tear), 8/68 (meniscus tear) • TSK-11: change of 5/44	ACL Tear ACL RSI (Low credibility)[35 43] K-SES (Expert opinion) TSK-17 (Low credibility)[35 44] TSK-11 (Expert opinion) Meniscus Tear TSK-17/TSK-11 (Expert opinion)
	Health-related quality of life instruments change scores: • EQ-5D-5L Index: change of 0.12 • SF-36 bodily pain: change of 8/100 • SF-12: change of 5.1/100 (PCS), 4.3/100 (MCS)	EQ-5D-5L (Expert opinion)[45] SF-36 (Expert opinion)[46] SF-12 (Very low credibility)[2]
	Patient Global Assessment (PASS) instrument change scores: • IKDC-SKF: 85/100 (ACLR), 69/100 (meniscal surgery) • $KOOS_{Pain}$: 93/100 (ACLR), 81/100 (meniscal surgery) • $KOOS_{Symptoms}$: 83/100 (ACLR), 78/100 (meniscal surgery) • $KOOS_{Sport/Rec}$: 88/100 (ACLR,) 80/100 (meniscal surgery) • $KOOS_{QOL}$: 79/100 (ACLR), 57/100 (meniscal surgery)	Expert opinion[2 11 16 17]
Muscle Strength	**Muscle strength**[a] • Peak concentric knee extensor strength (60°/s): variation[a] of 8.3% • Peak concentric knee extensor strength (180°/s): variation[a] of 2.9% • Peak isometric knee extensor normalised (BW) strength: change[b] of 1.7% • Peak concentric knee extensor strength LSI: change[b] of 10.5% • Peak concentric knee flexor strength (60°/s and 180°/s): variation[a] of 3.4% (60°/s) and 3.3% (180°/s)	GRADE[47] Very low
Hop Performance	**Hop performance**[b,c] • Crossover Hop Test (CHT): LSI change of 14.6% • Single Hop Test (SHT): LSI change of 6.7%-9.7% • Triple Hop Test (THT): LSI change of 12.0% • Vertical Hop: LSI change of 10.0% • 6-meter Timed Hop Test: LSI change of 15.5%	SHT, CHT, 6mTH, THT GRADE Very low[48] VH Expert opinion

*Change scores represent the most conservative average thresholds reported for persons who have had an ACL tear with or without a concomitant meniscal tear, or meniscal surgery, spanning gender and various timepoints post injury/surgery. As they are based on the most conservative threshold for what might be considered a severe intra-articular knee injury, they are unlikely to lead to the interpretation that a change was meaningful when it was not, but may lead to missing a meaningful change when one has occurred. Values are likely to change as new knowledge becomes available.

[a] Variation represents the coefficient of variation (standard deviation/mean)

[b] Change represents the standard deviation of change (SDC=1.96*√2*Standard Error of Measurement)

[c] Limb symmetry index (LSI) is influenced by changes in performance of both the injured and contralateral leg.

ACL (Anterior Cruciate Ligament), ACL-QOL (ACL Quality-of-Life Score), ACLR (ACL reconstruction), ACL-RSI (ACL Return to Sport after Injury scale), BW (body weight), EQ-5D-5L (EuroQol 5 Dimensions), GRADE (Grading of Recommendations, Assessment, Development and

Evaluation), IKDC-SKF (International Knee Documentation Committee Subjective Knee Form), K-SES (Knee Self Efficacy Scale), KOOS (Knee injury and Osteoarthritis Outcome Score including pain, other symptoms, function in sport and recreation and quality of life subscales), LSI (limb symmetry index), MCS (Mental Component Score), NRS (Numerical Rating Scale), OA (osteoarthritis), PTOA (post-traumatic osteoarthritis), PCS (Physical Component Score), PROs (patient-reported outcome measures), PTOA (post-traumatic osteoarthritis), QOL (quality-of-life), RM (repetition maximum), s (second), SF-12 (Short Form 12), SF-36 (Short Form 36), TSK (Tampa Scale of Kinesiophobia), VAS (Visual Analogue Scale), WOMET (Western Ontario Meniscal Evaluation Tool).

REFERENCES

1. Filbay S, Gauffin H, Andersson C, et al. Prognostic factors for tibiofemoral and patellofemoral osteoarthritis 32-37 years after anterior cruciate ligament injury managed with early surgical repair or rehabilitation alone. *Osteoarthritis Cartilage* 2021 doi: 10.1016/j.joca.2021.08.009 [published Online First: 2021/09/10]
2. Oiestad BE, Juhl CB, Culvenor AG, et al. Knee extensor muscle weakness is a risk factor for the development of knee osteoarthritis: an updated systematic review and meta-analysis including 46 819 men and women. *Br J Sports Med* 2021 doi: 10.1136/bjsports-2021-104861 [published Online First: 2021/12/18]
3. Silverwood V, Blagojevic-Bucknall M, Jinks C, et al. Current evidence on risk factors for knee osteoarthritis in older adults: a systematic review and meta-analysis. *Osteoarthritis Cartilage* 2015;23(4):507-15. doi: 10.1016/j.joca.2014.11.019 [published Online First: 2014/12/03]
4. Whittaker JL, Runhaar J, Bierma-Zeinstra S, et al. A lifespan approach to osteoarthritis prevention. *Osteoarthritis Cartilage* 2021;29(12):1638-53. doi: 10.1016/j.joca.2021.06.015 [published Online First: 2021/09/25]
5. Whittaker JL, Roos EM. A pragmatic approach to prevent post-traumatic osteoarthritis after sport or exercise-related joint injury. *Best Pract Res Clin Rheumatol* 2019;33(1):158-71. doi: 10.1016/j.berh.2019.02.008 [published Online First: 2019/08/23]
6. Whittaker JL, Truong LK, Losciale JM, et al. Efficacy of the SOAR knee health program: protocol for a two-arm stepped-wedge randomized delayed-controlled trial. *BMC musculoskeletal disorders* 2022;23(1):85. doi: 10.1186/s12891-022-05019-z [published Online First: 2022/01/27]
7. Patterson BE, Barton CJ, Culvenor AG, et al. Exercise-therapy and education for individuals one year after anterior cruciate ligament reconstruction: a pilot randomised controlled trial. *BMC musculoskeletal disorders* 2021;22(1):64. doi: 10.1186/s12891-020-03919-6 [published Online First: 2021/01/13]
8. Truong LK, Mosewich AD, Miciak M, et al. Balance, reframe, and overcome: The attitudes, priorities, and perceptions of exercise-based activities in youth 12-24 months after a sport-related ACL injury. *Journal of orthopaedic research : official publication of the Orthopaedic Research Society* 2022;40(1):170-81. doi: 10.1002/jor.25064 [published Online First: 2021/05/06]
9. Wallace IJ, Worthington S, Felson DT, et al. Knee osteoarthritis has doubled in prevalence since the mid-20th century. *Proc Natl Acad Sci U S A* 2017;114(35):9332-36. doi: 10.1073/pnas.1703856114
10. Blagojevic M, Jinks C, Jeffery A, et al. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. *Osteoarthritis Cartilage* 2010;18(1):24-33. doi: 10.1016/j.joca.2009.08.010 [published Online First: 2009/09/16]
11. Grindem H, Snyder-Mackler L, Moksnes H, et al. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *Br J Sports Med* 2016;50(13):804-8. doi: 10.1136/bjsports-2016-096031
12. Davis K, Schoenbaum SC, Audet AM. A 2020 vision of patient-centered primary care. *J Gen Intern Med* 2005;20(10):953-7. doi: 10.1111/j.1525-1497.2005.0178.x [published Online First: 2005/09/30]
13. Failla MJ, Arundale AJ, Logerstedt DS, et al. Controversies in knee rehabilitation: anterior cruciate ligament injury. *Clin Sports Med* 2015;34(2):301-12. doi: 10.1016/j.csm.2014.12.008 [published Online First: 2015/03/31]
14. Meade LB, Bearne LM, Sweeney LH, et al. Behaviour change techniques associated with adherence to prescribed exercise in patients with persistent musculoskeletal pain: Systematic review. *Br J Health Psychol* 2019;24(1):10-30. doi: 10.1111/bjhp.12324 [published Online First: 2018/06/19]
15. Babatunde F, MacDermid J, MacIntyre N. Characteristics of therapeutic alliance in musculoskeletal physiotherapy and occupational therapy practice: a scoping review of the literature. *BMC*

Health Serv Res 2017;17(1):375. doi: 10.1186/s12913-017-2311-3 [published Online First: 2017/06/01]
16. Gutnick D, Reims K, Davis C, et al. Brief action planning to facilitate behavior change and support patient self-management. *J Clin Outcomes Manag* 2014;21(1):17-29.
17. Coronado RA, Bird ML, Van Hoy EE, et al. Do psychosocial interventions improve rehabilitation outcomes after anterior cruciate ligament reconstruction? A systematic review. *Clin Rehabil* 2018;32(3):287-98. doi: 10.1177/0269215517728562 [published Online First: 2017/08/25]
18. Truong LK, Mosewich AD, Holt CJ, et al. Psychological, social and contextual factors across recovery stages following a sport-related knee injury: a scoping review. *Br J Sports Med* 2020;54(19):1149-56. doi: 10.1136/bjsports-2019-101206 [published Online First: 2020/02/16]
19. Ardern CL, Glasgow P, Schneiders A, et al. 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. *Br J Sports Med* 2016;50(14):853-64. doi: 10.1136/bjsports-2016-096278 [published Online First: 2016/05/27]
20. Kendrick T, El-Gohary M, Stuart B, et al. Routine use of patient reported outcome measures (PROMs) for improving treatment of common mental health disorders in adults. *Cochrane Database Syst Rev* 2016;7:CD011119. doi: 10.1002/14651858.CD011119.pub2 [published Online First: 2016/07/14]
21. Undheim MB, Cosgrave C, King E, et al. Isokinetic muscle strength and readiness to return to sport following anterior cruciate ligament reconstruction: is there an association? A systematic review and a protocol recommendation. *Br J Sports Med* 2015;49(20):1305-10. doi: 10.1136/bjsports-2014-093962 [published Online First: 2015/06/25]
22. Sinacore JA, Evans AM, Lynch BN, et al. Diagnostic Accuracy of Handheld Dynamometry and 1-Repetition-Maximum Tests for Identifying Meaningful Quadriceps Strength Asymmetries. *J Orthop Sports Phys Ther* 2017;47(2):97-107. doi: 10.2519/jospt.2017.6651 [published Online First: 2017/02/02]
23. Baechle TR, Earle RW. Essentials of strength training and conditioning. 4th ed. Champaigne IL: Human Kinetics 2016.
24. Kyritsis P, Bahr R, Landreau P, et al. Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture. *Br J Sports Med* 2016;50(15):946-51. doi: 10.1136/bjsports-2015-095908
25. Xergia SA, Pappas E, Zampeli F, et al. Asymmetries in functional hop tests, lower extremity kinematics, and isokinetic strength persist 6 to 9 months following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther* 2013;43(3):154-62. doi: 10.2519/jospt.2013.3967 [published Online First: 2013/01/17]
26. Moksnes H, Risberg M. Performance-based functional evaluation of non-operative and operative treatment after anterior cruciate ligament injury. *Scand J Med Sci Sports* 2009;19:345-55.
27. Kise NJ, Roos EM, Stensrud S, et al. The 6-m timed hop test is a prognostic factor for outcomes in patients with meniscal tears treated with exercise therapy or arthroscopic partial meniscectomy: a secondary, exploratory analysis of the Odense-Oslo meniscectomy versus exercise (OMEX) trial. *Knee Surg Sports Traumatol Arthrosc* 2019;27(8):2478-87. doi: 10.1007/s00167-018-5241-7 [published Online First: 2018/11/18]
28. Kotsifaki A, Van Rossom S, Whiteley R, et al. Single leg vertical jump performance identifies knee function deficits at return to sport after ACL reconstruction in male athletes. *Br J Sports Med* 2022;56(9):490-98. doi: 10.1136/bjsports-2021-104692 [published Online First: 2022/02/10]
29. Whittaker JL, Toomey CM, Nettel-Aguirre A, et al. Health-related Outcomes following a Youth Sport-related Knee Injury. *Med Sci Sports Exerc* 2018;51(2):255-63. doi: 10.1249/MSS.0000000000001787
30. Plisky PJ, Rauh MJ, Kaminski TW, et al. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther* 2006;36(12):911-9. doi: 10.2519/jospt.2006.2244

31. Léger LA, Mercier D, Gadoury C, et al. The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sport Science* 1988;6(2):93-101.
32. Gabbett TJ. Physiological characteristics of junior and senior rugby league players. *Br J Sports Med* 2002;36(5):334-9. doi: 10.1136/bjsm.36.5.334 [published Online First: 2002/09/28]
33. Risberg MA, Ekeland A. Assessment of functional tests after anterior cruciate ligament surgery. *J Orthop Sports Phys Ther* 1994;19(4):212-7. doi: 10.2519/jospt.1994.19.4.212 [published Online First: 1994/04/01]
34. Pasanen K, Parkkari J, Pasanen M, et al. Effect of a neuromuscular warm-up programme on muscle power, balance, speed and agility: a randomised controlled study. *Br J Sports Med* 2009;43(13):1073-8. doi: 10.1136/bjsm.2009.061747 [published Online First: 2009/07/23]
35. Macri EM, Young JJ, Ingelsrud LH, et al. Meaningful thresholds for patient-reported outcomes following interventions for anterior cruciate ligament tear or traumatic meniscus injury: an OPTIKNEE systematic review. *Br J Sports Med* Accepted
36. Tigerstrand Grevnerts H, Gravare Silbernagel K, Sonesson S, et al. Translation and testing of measurement properties of the Swedish version of the IKDC subjective knee form. *Scand J Med Sci Sports* 2017;27(5):554-62. doi: 10.1111/sms.12861 [published Online First: 2017/02/17]
37. Maheshwer B, Wong SE, Polce EM, et al. Establishing the Minimal Clinically Important Difference and Patient-Acceptable Symptomatic State After Arthroscopic Meniscal Repair and Associated Variables for Achievement. *Arthroscopy: The Journal of Arthroscopic & Related Surgery* 2021
38. Abram SGF, Middleton R, Beard DJ, et al. Patient-reported outcome measures for patients with meniscal tears: a systematic review of measurement properties and evaluation with the COSMIN checklist. *BMJ open* 2017;7(10):e017247.
39. Van Der Wal RJP, Heemskerk BTJ, Van Arkel ERA, et al. Translation and Validation of the dutch western ontario meniscal evaluation tool. *J Knee Surg* 2017;30(04):314-22.
40. Laigaard J, Pedersen C, Ronsbo TN, et al. Minimal clinically important differences in randomised clinical trials on pain management after total hip and knee arthroplasty: a systematic review. *Br J Anaesth* 2021;126(5):1029-37. doi: 10.1016/j.bja.2021.01.021 [published Online First: 2021/03/09]
41. Ingelsrud LH, Terwee CB, Terluin B, et al. Meaningful Change Scores in the Knee Injury and Osteoarthritis Outcome Score in Patients Undergoing Anterior Cruciate Ligament Reconstruction. *Am J Sports Med* 2018;46(5):1120-28. doi: 10.1177/0363546518759543 [published Online First: 2018/03/09]
42. Lafave MR, Hiemstra L, Kerslake S, et al. Validity, Reliability, and Responsiveness of the Anterior Cruciate Ligament Quality of Life Measure: A Continuation of Its Overall Validation. *Clin J Sport Med* 2017;27(1):57-63. doi: 10.1097/JSM.0000000000000292 [published Online First: 2016/01/19]
43. Slagers AJ, van den Akker-Scheek I, Geertzen JHB, et al. Responsiveness of the anterior cruciate ligament - Return to Sports after Injury (ACL-RSI) and Injury - Psychological Readiness to Return to Sport (I-PRRS) scales. *Journal of sports sciences* 2019;37(21):2499-505. doi: 10.1080/02640414.2019.1646023 [published Online First: 2019/07/25]
44. Huang H, Nagao M, Arita H, et al. Reproducibility, responsiveness and validation of the Tampa Scale for Kinesiophobia in patients with ACL injuries. *Health and quality of life outcomes* 2019;17(1):150.
45. Walters SJ, Brazier JE. Comparison of the minimally important difference for two health state utility measures: EQ-5D and SF-6D. *Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation* 2005;14(6):1523-32. doi: 10.1007/s11136-004-7713-0 [published Online First: 2005/08/23]
46. Concoff A, Rosen J, Fu F, et al. A Comparison of Treatment Effects for Nonsurgical Therapies and the Minimum Clinically Important Difference in Knee Osteoarthritis: A Systematic Review. *JBJS Rev* 2019;7(8):e5. doi: 10.2106/JBJS.RVW.18.00150 [published Online First: 2019/08/16]

47. Urhausen A, Berg B, Oiestad BE, et al. Measurement properties for muscle strength tests following anterior cruciate ligament or meniscal injury – where do we need to go and what tests to use? A systematic review of measurement properties for the OPTIKNEE initiative. *Br J Sports Med* Under Review
48. Berg B, Urhausen AP, Oiestad BE, et al. What tests should be used to assess functional performance in youth and young adults following anterior cruciate ligament or meniscal injury? A systematic review of measurement properties for the OPTIKNEE consensus. *Br J Sports Med* 2022 doi: 10.1136/bjsports-2022-105510 [published Online First: 2022/06/14]