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

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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.

Figure 1 OPTIKNEE seven-step consensus approach.

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]
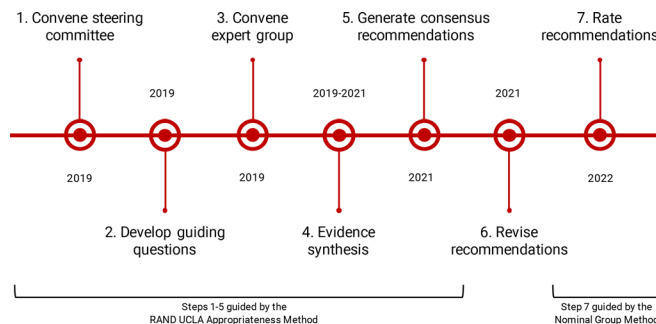
No clinical recommendations are available to guide interventions that might prevent symptomatic PTOA. Care pathways for people with knee injuries vary widely by practitioner, setting, diagnostic testing completed, surgery(s) performed, length/content of care and payment model.[19] Importantly, people 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/.

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

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)**.	a b
Prioritise people with symptoms and/or functional impairments that persist beyond usual recovery times, or with a subsequent injury ^**(d)**.	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)**.	ai aii aiii
Start these efforts as soon as possible after injury **(bi)** and continue across the lifespan **(bii)**.	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)**.	a b c d
Core components of ACL tear and ACLR exercise-based rehabilitation include:	ei eii eiii fi
• 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)**.	fii g
• 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)**.	
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)**.	ai aii aiii aiv
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)**.	av avi avii bi
Diagnostic imaging is only indicated when results will inform treatment planning **(c)**.	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)** **Other important muscle function measures** include: thigh muscle endurance **(ci)** and power **(cii)**, and trunk, hip, and leg muscle function **(d)**.	biii | ci | cii 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. **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)** **Other important clinical measures of functional performance** include: balance, agility or other tasks meaningful to the patient^ **(d)**.	a | bi | bii ci | cii | ciii civ | cv | 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 PTOAᵃ 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 MONITORᵇ 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 OUTCOMESᵇ 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-SKFᶜ, KOOSᵈ, or WOMETᵉ **(biv)**.	ai, aii, aiii, aiv (✔); av, avi, avii, bi (✔); bii, biii, biv (✔)
R5. HOW TO MONITOR MUSCLE FUNCTIONᶠ 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), includeᵍ: 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 PERFORMANCEʰ after a traumatic knee injury **Core research measures of functional performance** include: hop performance **(a)**. **Research measures of hop performance** includeⁱ: 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). ᵃExamples: NICE,[61] American College of Rheumatology,[62] European League against Rheumatism[63] definitions. ᵇDomains and instruments are presented in no particular order. Licencing requirements may apply. ᶜProvides an overall composite score of knee-related symptoms, function and sports activities. ᵈProvides 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 (KOOS₄) score of knee-related pain, other symptoms, function in sport and recreation, quality of life. ᵉProvides an overall composite score of knee-related physical symptoms, sports/recreation/work/lifestyle, and emotions. ᶠThe capacity of a muscle to do work (eg, strength, power, endurance). ᵍStrength 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. ʰThe action of carrying out or accomplishing a movement, movement task or movement activity. ⁱHop 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.

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.

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