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Evidence Review for Preventing Osteoarthritis After an Anterior Cruciate Ligament Injury: An Osteoarthritis Action Alliance Consensus Statement

Osteoarthritis Action Alliance, Secondary Prevention Task Group
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Context: The Osteoarthritis Action Alliance formed a secondary prevention task group to develop a consensus on secondary prevention recommendations to reduce the risk of osteoarthritis after a knee injury.

Objective: Our goal was to provide clinicians with secondary prevention recommendations that are intended to reduce the risk of osteoarthritis after a person has sustained an anterior cruciate ligament injury. Specifically, this manuscript describes our methods, literature reviews, and dissenting opinions to elaborate on the rationale for our recommendations and to identify critical gaps.

Design: Consensus process.

Setting: Virtual video conference calls and online voting.

Patients or Other Participants: The Secondary Prevention Task Group consisted of 29 members from various clinical backgrounds.

Main Outcome Measure(s): The group initially convened online in August 2020 to discuss the target population, goals, and key topics. After a second call, the task group divided into 9 subgroups to draft the recommendations and supportive text for crucial content areas. Twenty-one members completed 2 rounds of voting and revising the recommendations and supportive text between February and April 2021. A virtual meeting was held to review the wording of the recommendations and obtain final votes. We defined *consensus* as >80% of voting members supporting a proposed recommendation.

Results: The group achieved consensus on 15 of 16 recommendations. The recommendations address patient education, exercise and rehabilitation, psychological skills training, graded-exposure therapy, cognitive-behavioral counseling (lacked consensus), outcomes to monitor, secondary injury prevention, system-level social support, leveraging technology, and coordinated care models.

Conclusions: This consensus statement reflects information synthesized from an interdisciplinary group of experts based on the best available evidence from the literature or personal experience. We hope this document raises awareness among clinicians and researchers to take steps to mitigate the risk of osteoarthritis after an anterior cruciate ligament injury.

Key Words: patient education, rehabilitation, physical activity, injury prevention, psychological stress

Key Points

- Besides optimizing short-term outcomes (eg, return to activity), a focus on secondary prevention of osteoarthritis can help preserve lifelong quality of life and wellness.
- With an intent to reduce the risk of osteoarthritis after a person sustains an anterior cruciate ligament injury, we offered recommendations to comprehensively address physical and psychosocial impairments.

Many knee injuries occur in young, physically active people. More than 1 in 3 anterior cruciate ligament (ACL) reconstructions are performed in high school or college athletes in the United States.[1–3] Reconstruction of the ACL often leads to positive outcomes, such as a return to physical activity (eg, sport, occupational, recreational). Unfortunately, for at least 1 in 3 young patients, a knee injury is a catalyst to living with knee osteoarthritis for most of their lives.[4–6] Many younger adults with knee osteoarthritis experience poor quality of life, diminished physical activity levels, and decreased physical function, all of which may lead to long-term psychosocial or psychological (eg, depression) and economic (eg, high medical costs) concerns and comorbidities (eg, cardiovascular disease).[7–10] In the United States, the economic burden of individuals with a history of ACL reconstruction is greater than $7.6 billion per year.[7]

Prevention of the long-term burden of knee osteoarthritis among people after an ACL injury is urgently needed. Unfortunately, the current literature on secondary prevention for people with an ACL injury lacks high-quality evidence. This deficiency was highlighted by the lack of secondary prevention strategies in the "National Public Health Agenda for Osteoarthritis: 2020 Update."[11] In the absence of consistent evidence-based conclusions from the literature, consensus guidelines can be established by leveraging expert opinion and clinician experience. Hence, the Osteoarthritis Action Alliance formed the interdisciplinary Secondary Prevention Task Group (Supplemental Table) to develop consensus-based secondary prevention recommendations for clinicians intended to reduce the risk of osteoarthritis after a person has an ACL injury and to help define directions needed for future research. The task group proposed a comprehensive list of 16 recommendations, conducted extensive literature reviews, and completed 3 rounds of voting and revisions. Consensus was reached on 15 recommendations that encompass a broad approach to addressing the mental and physical well-being of patients to mitigate their risk of osteoarthritis from the time of injury until the diagnosis of osteoarthritis, when osteoarthritis treatment guidelines should be consulted.[12–14] The following sections describe the consensus methods, the literature reviews to justify each recommendation, and all dissenting opinions by members of our task force to facilitate future discussion. We included the 16th recommendation, which failed to achieve consensus, because it may inspire further discussions and research. Overall, our expert panel offered this consensus statement based on their interpretation of the literature and clinical experience to fill a unique gap in an emerging field with insufficient evidence to inform clinical practice guidelines. These recommendations require high-quality research to justify and refine them and ultimately to help inform clinical practice guidelines. We envision that this document is a starting point and will need to be revised in 5 to 10 years to reassess the recommendations based on emerging evidence.

METHODS

The Osteoarthritis Action Alliance is a national coalition of concerned organizations committed to elevating osteoarthritis (OA) as a national health priority and promoting effective policy solutions that address the individual and national tolls of OA. The Alliance was mobilized by the Arthritis Foundation and the Centers for Disease Control and Prevention, with the Thurston Arthritis Research Center at the University of North Carolina at Chapel Hill as the lead agency. The Osteoarthritis Action Alliance formed the Secondary Prevention Task Group to develop a consensus on secondary prevention recommendations in order to

reduce the risk of OA after a knee injury. The associate director of the Osteoarthritis Action Alliance sent an electronic invitation to members of the Steering Committee and Primary Prevention Task Group. The Steering Committee includes representatives from lead partner organizations: the American Medical Society for Sports Medicine, Arthritis Foundation, Association of Rheumatology Professionals, Osteoarthritis Research Society International, and US Bone and Joint Initiative. Other organizations are also represented on the steering committee, including the National Athletic Trainers' Association, American Chronic Pain Association, Movement is Life, Alliance for Balanced Pain Management, National Recreation and Park Association, and American Medical Women's Association. The invitation encouraged recipients to share it with other contacts who might be interested. The task group consisted of 29 members, including 4 staff members from the Osteoarthritis Action Alliance (Supplemental Table). The remainder of the task group were volunteers from the constituent organizations with various backgrounds, including athletic trainers (ATs), orthopaedic surgeons, physical therapists, psychologists, and sports medicine physicians.

On August 28, 2020, 25 task force members met online to discuss the target population, goals, and key topics. The group agreed that the target population would be people $\leq$40 years of age with an ACL injury from the time of injury until a diagnosis of knee OA. We focused on individuals $\leq$40 years old because this population would include most people who experience an ACL injury and would be unlikely to have OA at the time of injury. The short- to mid-term goals were to

1. Promote a patient's role in shared and informed decision-making (foster informed consumers);
2. Educate people about their injury and recovery (eg, what to expect, long-term risks, risk modifiers), coping strategies, maintaining or improving self-efficacy, the importance of adherence, stress management, and goal setting;
3. Optimize physical activity (eg, a total return to previous activities or activity modification);
4. Prevent or reduce chronic symptoms (eg, knee pain, poor quality of life, functional limitations, fear);
5. Prevent subsequent injuries; and
6. Reduce psychological stress (eg, related to return to activity, communication with a clinician).

The recommendations were designed with the overarching long-term goal of providing clinicians with evidence and treatment strategies intended to prevent or delay the onset of symptomatic OA, prevent OA-related disability, and improve quality of life. The group also agreed to the need to recommend key outcomes to monitor and interventions to consider. Specifically, the group agreed to consider education, exercise, exposure therapy, mindfulness therapies, secondary injury prevention, use of technology, and coordinated care strategies. One task force member drafted a summary of key topics from the first call and shared it with the task force on September 2, 2020. These topics were further refined during an online meeting on October 14, 2020.

On November 3, 2020, the task group was partitioned into 9 subgroups to draft recommendations and supportive text for crucial content areas based on published evidence and clinical experience (Supplemental Table). The task group received a draft of these recommendations and supportive text, and the first round of voting occurred from January 25 to February 15, 2021. We defined *consensus* as $>$80% of voting members supporting a proposed recommendation. A voter who could not support the current wording was asked to provide recommended changes to the text. Twenty-two members (76%) voted in round 1. Based on feedback from round 1 voting, the subgroups revised the recommendations and supportive text for each content area (February 16–April 13, 2021). In addition, some subgroups reached out to other content experts within the task group to assist with the revisions and ensure that the revisions were responsive to feedback. A second round of voting occurred online from April 16 to 30, 2021. Twenty-one of the 22 members (96%) from round 1 voted in round 2.

After the second round of voting, the task group convened a virtual meeting to review the wording of the recommendations and provide final votes. During this meeting, attendees agreed that the text for the psychological interventions should be reevaluated and updated. Then over the next 10 days, online voting for the new psychological recommendations occurred. Furthermore, task force members who could not attend the May 27 meeting voted on all the recommendations. Everyone who voted in round 2 voted in round 3.

After the final round of voting, 3 task group members (J.B.D., H.K.V., T.H.T.) harmonized the text into a single document. Next, they forwarded this document to individuals who voted against a specific recommendation to ask for dissenting opinions. Finally, a complete draft was forwarded to the 21 people who voted in rounds 2 and 3. After feedback was received, the document was shared with the task group members who participated in the initial development of the consensus statement but did not write any of the recommendations or vote. This subset served as a final review team. The lead author (J.B.D.) revised the document based on this feedback and shared the document with the task group and the Osteoarthritis Action Alliance Steering Committee for final approval.

We ordered the recommendations in part on the timing of when they might be implemented for each patient. However, the last 4 overarching recommendations (No. 13–16; eg, social support, use of technology, and coordinated care programs) could help implement the preceding recommendations.

RECOMMENDATIONS

1. Provide accessible resources that health care providers can distribute to a patient

Patients who sustain traumatic musculoskeletal injuries need to better understand their risk of developing OA. Only 27% of patients with an ACL injury remembered discussing their OA-related risk with a health care provider.[15] Discussions about OA should center on what patients can do to mitigate the development and progression of the condition. In addition, health care providers can implement communication methods to reduce the potential concerns associated with limited patient health literacy. These methods include avoiding medical jargon, engaging in patient questions, explaining unfamiliar terms, and using "teach-back" to ensure understanding.[16] Finally, health care providers, especially those overseeing rehabilitation after an

ACL injury, need to become more aware of their patients' risk for OA and how to educate patients about this risk.[17,18]

Health care providers should prompt questions, as patients often use outside sources to obtain information.[19,20] It is pertinent for the provider to engage with patients about their access to available information.[20] Providers' notes accessible through electronic health records are not good information sources for most patients.[21] AskShareKnow[22] is a proven method of engaging patients to ask more questions. It is composed of 3 generic questions: (1) What are my options? (2) What are the possible benefits and harms of those options? (3) How likely are each of these benefits and harms to happen to me? These questions can be a springboard for further discussion with patients about reducing the risk of OA after an injury.

2. Provide educational opportunities to health care professionals regarding how to best educate patients about OA prevention

Incorporating information about effective methods of educating patients about OA after ACL injury, and especially about prevention, into entry-level education for all health care providers is essential. Furthermore, we need more continuing education opportunities for health care providers regarding how to best educate patients after ACL injury about OA. Future researchers should examine the most effective training methods for providers and identify which methods optimize patient literacy about the OA risk.

3. Develop a tool kit for the caregiver to identify a patient's willingness for rehabilitation and the patient's preferred mode of obtaining self-management resources

We recommend that a tool-kit questionnaire consisting of 2 to 4 simple questions be developed to incorporate ways of delivering self-management strategies. The tool kit would identify the patient's willingness to manage the injury and identify limitations to obtaining, learning, and retaining these findings. If the patient is originally unwilling to manage the situation, then health care professionals should provide the patient or a willing or trusted family member with more information about the rationale for managing the injury and some management strategies. The tool kit would also help the health care provider determine the best delivery mode (eg, discussion, doctor's notes, electronic medical records, handouts, multimedia educational tools, telephone coaching). Delivery of care during the COVID-19 pandemic has taught us much about the value of technology-enabled interactions with patients. Patients have favorably endorsed virtual or phone sessions to enhance their education after an injury.[23] Health care providers should explore newer and upcoming technology to deliver health information, such as podcasts or social media, about OA.[24] Patient education about the potential for OA needs to begin at the time of the initial injury and recur at regular intervals after injury or reconstruction. Future investigation is needed to establish the best frequency for this education. Still, initial efforts could coincide with traditional follow-up visits (eg, initial clinic visit, acute postoperative visit, 6-month follow-up, return-to-participation assessment) to minimize the initial burden on the health care system.

Dissenting Opinion. Not all people who experience an ACL injury have a *caregiver* (eg, a family member or paid person who regularly looks after the patient) who will be involved in the ACL injury recovery. The term *caregiver* may lead readers to assume the goal is to develop a tool kit for parents, especially for patients <18 years of age. This recommendation encourages the development of a tool kit for patients, parents or caregivers, and health care professionals.

4. After an ACL injury or reconstruction, individuals should undergo a supervised, comprehensive, and progressive rehabilitation program to address impairments and neuromuscular deficits, specifically those related to quality of movement, knee range of motion, quadriceps muscle strength and performance, and functional performance before return to activity

Impairments in body structure and function that persist after an ACL injury or reconstruction are associated with subsequent radiographic abnormalities (eg, joint space narrowing), making it critical to resolve these impairments during postoperative rehabilitation early after the injury or ACL reconstruction. Nearly 50% of young and active individuals after ACL reconstruction are cleared for return-to-sport participation with altered movement patterns.[25–28] Furthermore, many patients return to sport with impaired muscle function, asymmetries in vertical ground reaction force and loading rate, and biomechanical deficits associated with quadriceps weakness.[25–28] Early optimization of knee range of motion, quadriceps strength, and movement patterns could help prevent or delay the onset of OA in this high-risk population.

Restore Range of Motion of the Involved Knee to Match the Uninvolved Knee, Emphasizing Extension. After an ACL reconstruction, more than 25% of individuals have side-to-side differences in knee extension $>5°$ and this can persist up to a month.[29] Early loss of knee range of motion (as small as 3° to 5°) after an ACL reconstruction, especially with extension, may make the patient more than twice as likely to develop radiographic OA, particularly when coupled with concomitant meniscectomy or cartilage damage at the time of ACL reconstruction.[30–32] Therefore, early joint motion after ACL reconstruction is an important component of comprehensive rehabilitation. Immediate passive and active motion ($\leq$1 week) after ACL reconstruction should be implemented to increase joint range of motion (from full extension to $\geq 90°$ of flexion), reduce joint pain, and lessen the risk of adverse responses of surrounding soft tissues (eg, arthrofibrosis).[30] In weeks 2 through 8 after surgery, a gradual but consistent increase in motion to full flexion can help restore knee mobility.[30]

Restore Quadriceps Femoris Strength and Function to Improve Physical Function and Protect Joint Structures. The quadriceps muscles are the primary stabilizers of the knee and play a critical role in joint dynamic stability and loading, particularly in ground reaction force and knee kinematic and kinetic patterns that may protect cartilage.[33] Eccentric action of the quadriceps muscles during joint-loading activities facilitates knee flexion to absorb shock. Quadriceps weakness is a significant risk factor for the development and progression of knee OA.[34] Unfortunately, approximately 50% of young and active individuals are

cleared for high-level sports activities with significant quadriceps femoris strength deficits in the involved limb compared with the uninvolved limb.[26,35,36] These deficits can range from 15% to 40%.[30] The deficit adversely affects mechanical loading[37] and contributes to unfavorable changes to cartilage (eg, lower proteoglycan density, more severe patellofemoral cartilage damage).[38–42] In addition to deficits in muscle peak torque or force output, the rate at which torque develops independently contributes to the individual's ability to dissipate lower limb loading and generate the rapid, forceful movements that are common in sports participation.[43,44] Women have bilateral quadriceps femoris weakness and a slower rate of torque development than men during the first year after ACL reconstruction.[45]

Reversing strength loss after ACL injury or reconstruction can change the trajectories of physical function and clinical markers of OA. Although quadriceps femoris strength deficits relate to impaired knee-related function, functional performance, altered movement patterns, and cartilage changes,[26,35,36,40] resolving these deficits produces functional performance similar to that observed in healthy individuals.[35] Authors[46] of a 5-year prospective study showed that more symmetrical quadriceps femoris strength was associated with lower odds of clinical knee OA. For every 1% increase in limb quadriceps femoris strength symmetry, the odds of clinical knee OA were reduced by 4%. Restoring quadriceps femoris strength and performance are key criteria for progressing rehabilitation and preparing for the return to unrestricted sports participation.[47,48] Implementing functional closed chain strengthening exercises, such as limited-range-of-motion wall slides and step-ups, early in the recovery process (>2 weeks) and slowly progressing weight bearing over 10 weeks[30] can help promote strength return. Electrical stimulation for 6 to 8 weeks after an ACL reconstruction can augment muscle strengthening and improve neural drive to increase quadriceps muscle strength and enhance short-term functional outcomes.[49] Weight-bearing and non–weight-bearing concentric and eccentric exercises should be implemented early after ACL reconstruction, 2 to 3 times/wk for 6 to 10 months, to increase thigh muscle strength and functional performance. Recommendations for a safe return to activity should include achieving quadriceps strength symmetry >90%.[30]

Resolve Altered Movement Patterns Early After ACL Reconstruction. Although quadriceps femoris strength is an important component of return to activity, persistent aberrations in gait or side-to-side loading mechanics need to be corrected with strengthening.[46] An ACL injury or reconstruction may produce variable effects on knee motion. After an ACL reconstruction, many people have increased sagittal-plane knee range of motion during the first year after surgery and an acute reduction and then gradual increase in knee-extensor moment.[50] Furthermore, they have lingering signs of anteroposterior instability and tibial rotation during the stance phase of walking.[50] The variability of kinematic and kinetic measures during gait suggests that patients have unique responses to their specific injury or surgery. Some individuals after ACL reconstruction demonstrate elevated knee-adduction–moment impulses, which are associated with altered cartilage composition.[51] Others show reductions in peak knee-flexion moment and flexion angle during walking gait from 6 months to year 3.[52] Biomechanical patterns early after ACL reconstruction may predict persistent abnormalities in the cartilage and meniscus. During drop-jump landings, vertical ground reaction forces, knee-flexion angles, and knee moments are 4% to 46% lower at 6 months post–ACL reconstruction. These patterns are associated with persistent meniscal and cartilage abnormalities 3 years later, despite the resolution of biomechanical differences.[52,53]

During a comprehensive and progressive rehabilitation program, side-to-side lower limb asymmetries in movement coordination and performance should be monitored, and neuromuscular reeducation training should be incorporated with muscle-strengthening exercises for the quadriceps femoris and other muscles that influence the lower extremity kinetic chain (eg, hip abductors, hip rotators). In addition, persistent deficits in strength and neuromuscular control or poor quality of movement should continue to be addressed in the clinic or through sport-specific rehabilitation programs before return to activity. Future researchers should follow people long after an ACL injury to clarify the effects of strength and range-of-motion changes on long-term joint health.

5. Before full reintegration into a sport, individuals should gradually resume sport-specific training to restore metabolic conditioning, build tolerance to chronic training loads, and adopt desired movement strategies

Premature return to sport may be associated with early OA[54] and ACL reinjury.[55] In addition, the ACL injury incidence rate is 15 times higher among people with a prior ACL reconstruction than in people without that injury history.[56] These adverse outcomes may result from insufficient physical conditioning and strength,[57–60] inadequate tolerance of real training loads,[55] and lingering biomechanical asymmetries[61–63] at the time of return to sport. Thus, a layered approach to preparing athletes for return to sport that includes progressive and overlapping conditioning activities may help develop tolerance to training loads and improve contextual movement strategies to prevent poor outcomes.

Physical Conditioning and Building Chronic Training Tolerance. Indirect evidence suggests that fatigue affects the ACL injury risk factors of neuromotor function, muscle rate and amount of force development, and movement strategies.[55] Furthermore, more ACL injuries occur in the second halves of competitions in soccer and a variety of high school sports.[64,65] Monitoring fatigue in both the involved and uninvolved limbs during recovery while the patient performs functional hop tests may add insight on the readiness to return to sport. The uninvolved limb should be monitored because a fatiguing hop-test battery affected this limb more than the ACL reconstruction limb among athletes >6 months post–ACL reconstruction.[66] Greater fatigue in the uninvolved limb is likely a function of detraining and should be considered when deciding on a person's readiness to reengage in activity.[66] Developing aerobic and anaerobic conditioning with muscle strength in both limbs during functional recovery enables athletes to work at higher intensities for longer durations and to return to activity without the risks associated with fatigue.[55] A progressive increase in chronic training loads (total volume and frequency of training sessions, increased intensity of

activity over time toward peak workload) induces tissue adaptation. It also prevents potential underloading before introducing real sport demands.[55,59] Readiness to progress the workload and return to sport is complicated and depends on indices of tissue health, stresses on the tissue, and modifiers of risk tolerance.[67]

A gradual, multifaceted sport reintegration plan with balanced benefits and risks[68] can restore fitness and neuromotor performance. For example, in a 10-month intervention study,[69] 50 soccer players with ACL reconstruction participated in on-field training and gradually introduced ball-handling activities, higher running intensities, and an increased technical level of ball activities. This program resulted in 23% to 86% gains in the anaerobic threshold knee–flexion-extension strength at the end of rehabilitation. Gradual reintroduction of controlled activities in a sport-specific environment can occur as performance and confidence improve. Then the complexity and involvement with teammates can increase. Emerging evidence and expert opinion indicate that rehabilitation practice should support an athlete's return to a specific sport environment. Athletes who compete on the field, court, track, or rink benefit from exposure to activities on-site while conditioning is being restored.[55,70,71] Early reintroduction to sport-specific demands can include graded exposure to different directions of motion (forward, backward, lateral direction changes, or varying patterns). Intermediate on-site training can include low-intensity agility and neuromuscular drills and power development during controlled changes in direction. These early stages emphasize functional strengthening and neuromuscular enhancement.[71,72] In later rehabilitation phases, an athlete can focus on responding to unanticipated demands (eg, changes in direction and speed with greater perceptive and neurocognitive demands)[68] and developing more endurance. If return-to-sport criteria are achieved, the athlete can participate in progressively more intensive noncontact team drills, practices, and scrimmages over time.[70]

Adopt Desired Movement Strategies to Facilitate Return to Sport. Nine months post–ACL reconstruction, several motion features associated with ACL injury occur during unplanned 90° cutting maneuvers,[62] single-legged jumps and hop tasks, and double-legged drop jumps.[63] These features include interlimb asymmetries in internal knee-valgus moment, internal knee-rotation angle, and external ankle-rotation moment and a shift of center of mass toward the involved side. Thus, beyond the restoration of greater than 90% limb symmetry in strength, additional advanced training may be needed to restore the explosive performance[55] needed when transitioning back to sport. Experts[8,73] describe the importance of developing contextual sport movement through a phased progression from foundational movement training with loading (eg, back squats, unilateral tasks, bilateral landing control) to high-load sport-specific movement retraining (eg, plyometrics, speed, and acceleration) and finally to on-field sport motion. In addition, training interventions that improve performance of risky movements may help prevent recurrent ACL injury. Consensus groups[74,75] agree that individuals should be able to pass a standard battery of objective movement tests after interventions and before full return to sport (eg, movement quality, hop tests, strength, range of motion), but the specific tests vary. For example, athletes who fail to complete their rehabilitation and fail all hopping, running speed, agility, and strength tests are 4 times more likely to rerupture the ACL than athletes who pass these tests.[76]

Future researchers should determine clear definitions of return to sport for each sport activity and which metrics should comprise the ideal test battery for progression in rehabilitation and return to sport.[67,74]

6. Individuals after an ACL injury or ACL reconstruction should be encouraged to meet the "Physical Activity Guidelines for Americans" (2nd edition)

Sport is commonly the main component of physical activity for young people.[77] When individuals with an ACL injury or ACL reconstruction stop sport participation, often physical activity is reduced,[77,78] which elevates the risk of chronic morbidity associated with an inactive lifestyle.[79] Historically, resuming physical activity after ACL reconstruction for overall health benefit has been underemphasized in clinical practice or research. Lower physical activity levels are prognostic of future knee pain and symptoms as well as a lower quality of life.[80] Clinicians have an opportunity to shape a positive long-term health trajectory, as physical activity can help counter comorbid disease onset and risk factors associated with OA onset and progression.

Physical Activity Patterns and Related Health Considerations. The current "Physical Activity Guidelines for Americans,"[81] issued in 2018 by the US Department of Health and Human Services, recommend that adults participate in at least 150 minutes of moderate-to-vigorous aerobic physical activity and at least 2 days of strengthening activity each week. Unfortunately, young people with a history of an ACL injury are 2 to 4 times less likely to meet these guidelines, even after return to sport.[79] Furthermore, up to 67 months after an ACL reconstruction, young adults spent 15% to 41% less time in moderate-to-vigorous aerobic physical activity. They were also less likely to meet national physical activity guidelines than those without a history of injury.[45,77,82–84] Specifically, individuals with a history of ACL reconstruction

a. accumulated an average of 16% fewer steps per day,[82,84]
b. met a daily 10 000 step count target at a proportionally lower rate,[82]
c. accrued fewer steps at moderate-to-vigorous cadence,[84] and
d. failed to meet physical activity guidelines as frequently as healthy individuals without a history of ACL injury.[45,82]

Consequently, people with a history of ACL reconstruction have elevated risks for other lifestyle-related chronic diseases, including cardiovascular disease, hypertension,[10,85] obesity,[78] and depression.[86] Significant weight gain can occur in adolescents during the first year after an ACL reconstruction.[78] Adults who incur a second ACL injury are 3.8 times more likely to be on a weight gain trajectory than those who are not reinjured.[87] Concerning the cardiovascular system, the incidence of myocardial infarction increases by 50% with a history of ACL injury.[10] Furthermore, the depression incidence may be as high as

42% among people after an ACL reconstruction.[86,88] Thus, physical activity may promote overall health and well-being via weight maintenance and systemic health.

Physical Activity for Long-Term Health. There is a clear and substantial benefit of regular physical activity (land and aquatic) on knee pain symptoms and physical function, with moderate effects on quality of life, regardless of variations in dosing.[89,90] Resistance exercises also significantly affect knee-related quality of life.[90] Cardiovascular disease risk decreases 5% to 21% for every 1000 daily steps taken,[91] and a dose-response relationship exists between physical activity levels and incident hypertension.[92] Also, strong evidence from the Physical Activity Guidelines Committee exists to show that prevention of weight gain is most effective with participation in more than 150 minutes of moderate-to-vigorous physical activities a week.[93] Furthermore, meeting physical activity guidelines can protect against depression.[94]

Health care professionals should engage patients in discussions on how to safely meet physical activity guidelines throughout the recovery process. These discussions will require health care professionals to respect precautions and a person's ability early in recovery. Furthermore, discussions should address how to progress to allowable activities throughout rehabilitation and emphasize maintaining recommended physical activity levels throughout life. Sport activities are a safe and effective strategy to meet physical activity guidelines. Participation in various sport or recreational activities may even protect against the development and progression of knee symptoms and OA.[89,95–99] Irrespective of sport or activity type, moderate daily recreational activities (performed as recommended for health benefit) are not a consistent risk factor for clinical or radiographic knee OA.[34,100] Regular engagement in select sports with high load or high injury risk (eg, soccer or elite-level long-distance running, weight lifting, or wrestling) may, however, elevate the risk for knee OA[101] or medial-compartment cartilage damage.[102] People with greater underlying joint pathology demonstrate more knee-joint structural change with step counts greater than 10 000 than with step counts less than 10 000.[103] Therefore, among persons with a history of an ACL injury or ACL reconstruction, it is prudent to achieve physical activity guidelines using a variety of physical activities with moderate knee loading over the long term, especially among subgroups of people at higher injury risk.

Authors of future studies need to provide more specific recommendations for prescription and dosing and promotion of physical activity, including aerobic and strengthening activities,[90] after ACL reconstruction and determine which patient subgroups are most protected against OA by various activity types.

7. Psychological skills training should be considered as part of the short- and long-term care plans after ACL injury and reconstruction to prevent reinjury, improve overall health and wellness, and encourage engagement in and adherence to physical activity

Despite successful ACL reconstruction, only 44% of these athletes return to competitive levels of physical activity.[104] Primary barriers to return to physical activity are elevated injury-related fear (ie, *kinesiophobia*), decreases in *self-efficacy* (ie, the belief in one's ability to complete a task), and pain. Psychological skills training includes mindfulness meditation, relaxation skills, self-knowledge mastery, mental imagery, goal setting, and self-talk.[105] Psychological skills training fosters focus, acceptance, attentional control, decision-making, and a mindful state.[106] It may improve overall well-being, stress coping, development of the most productive mindset, and confidence building before surgery and during rehabilitation or return to activity.[107] Skills are often coupled into a multimodal intervention (eg, relaxation and imagery,[108] goal setting, and mindfulness[109]). Various trained clinicians (eg, physicians, nurses, physical therapists, ATs) and other sport science–trained mental health professionals (eg, mental performance consultants, psychologists, mental health counselors) can teach these skills.

Mindfulness, Mental Imagery, and Other Psychological Skills for Early Recovery and Improved Long-Term Outcomes After ACL Injury or Reconstruction. *Mindfulness* is defined as paying attention in a particular way, on purpose, in the present moment, and nonjudgmentally.[110] In group settings, the teaching of mindfulness involves developing an awareness of thoughts, feelings, or bodily sensations; bringing attention to breathing; and expanding attention to the body. Other techniques include developing balance in logical and emotional thought and the ability to focus on "how" skills (eg, nonjudgmental, one-mindful [being present in the moment], and effective) and "what" skills (eg, observing, describing, and participating). A person can practice mindfulness during short pauses in everyday life and incorporate mindfulness into daily movements, such as walking and quiet sitting. Mindfulness can also be merged with yoga, tai chi, or other sports. Among individuals with a history of an ACL injury, mindfulness could bring balance to logical and emotional thought, improve situational awareness for subsequent injury, reduce stress and kinesiophobia, and prevent new injuries in the short to mid term. Mindfulness can also improve acute or postsurgical pain.[111] From studies of people with knee OA, we can infer that if chronic pain occurs after an ACL injury, a mindfulness intervention (eg, tai chi, yoga, meditation) may improve the pain, pain coping, anxiety, stress, depression, kinesiophobia, quality of life, physical function, postural control, and responsiveness to other therapies.[112–119]

Mental imagery is the self-directed imagining or visualizing of specific events, actions, or outcomes, including associated feelings and responses, to increase motivation toward a target action or task.[120] Commonly used imagery practices after an injury include healing imagery (eg, imagining tissue healing), soothing imagery (eg, imagining lying on a beach), and performance imagery (eg, imagining completing a task, such as knee extension). Mental imagery techniques can reduce pain before surgery, injury-related fear, knee symptoms, and the number of days people use crutches after an ACL injury or reconstruction.[121–123] Among athletes with an ACL reconstruction, guided imagery and relaxation initiated within 1 week of surgery lowered pain by 85% and reinjury anxiety by 87% and was associated with greater gains in knee isokinetic strength.[108] Furthermore, a guided imagery–physical ther-

apy intervention (ie, goal setting, motivational healing, exercise rehearsal, relaxation) improves self-efficacy.

Mental Flexibility for Prevention of Reinjury. The musculoskeletal reinjury risk among high school or collegiate athletes may be reduced by increasing mental flexibility. *Mental flexibility* consists of reducing the perception of stress, supporting nonjudgmental awareness, and increasing levels of a positive emotional state.[124,125] Thus, adding techniques such as mindfulness meditation or mental imagery into the daily routine may improve safety during activity after ACL injury.

Authors of future high-quality investigations should systematically study the differential efficacy of psychological skills training on knee health trajectories, progression of OA, and quality of life years after an ACL injury or reconstruction. Moreover, researchers need to identify the best responders to different psychological skills training programs in order to adopt a precision approach to preventing disability and optimizing quality of life. These studies will strengthen the evidence for psychological skills training after an ACL injury or reconstruction.

Dissenting Opinion. The language of the recommendation is too strong for this emerging field, which draws on evidence from other sports injuries or OA. Many patients experience injury-related fear after an ACL reconstruction. Elevated injury-related fear, or kinesiophobia, relates to a greater risk of secondary ACL injury. Although psychological skills training may be beneficial for patients after an ACL reconstruction, we lack sufficient evidence to integrate psychological skills training into the rehabilitative care of patients after an ACL reconstruction. Specifically, it remains unclear if psychological skills training has a clinically meaningful effect on injury-related fear, kinesiophobia, or, most importantly, the risk of secondary injury.

8. Graded-exposure therapy can be added to therapy programs after ACL injury and reconstruction to overcome fear and prevent reinjury

In addition to fear of reinjury, kinesiophobia is also related to asymmetries in ground reaction force and rectus femoris and biceps femoris activation at 6 months after an ACL reconstruction.[126] Patients who exhibit heightened levels of injury-related fear after traumatic knee injury are 13 times more likely to sustain a secondary knee injury within 24 months of clearance to return to sport.[127] Up to 10 years post–ACL reconstruction, kinesiophobia relates to knee symptoms and function.[128] Therefore, overcoming psychosocial barriers to therapy participation and preventing reductions in activity are important after ACL injury or ACL reconstruction to promote better long-term knee health.

Graded-Exposure Therapy and Early Recovery After ACL Injury or ACL Reconstruction. Graded activity and graded exposure address pain-related avoidance behaviors and pain-related fears, respectively, by providing positive reinforcement when a patient successfully completes the fearful task without experiencing pain or injury.[109] *Graded activity* addresses pain-related avoidance behaviors in a paced, collaborative, and goal-driven manner that requires establishing a time- or intensity-based quota to complete challenging tasks patients avoid because of pain. The Photographic Series of Sports Activities for Anterior Cruciate Ligament Reconstruction[129] can be used to identify specific activities that may be considered fearful after ACL reconstruction. Clinicians can monitor the effectiveness of the graded-exposure therapy on injury-related fear using instruments such as the Tampa Scale of Kinesiophobia,[130] the Tampa Scale of Kinesiophobia-11,[131] or the Anterior Cruciate Ligament Return to Sport After Injury Scale.[132] Athletes with an ACL reconstruction indicated that graded exposure was part of a "preparation of body and mind" framework for returning to sport.[107]

The efficacy of graded activity or graded exposure on reducing injury-related fear has been well studied in patients with musculoskeletal injuries, such as low back pain or total knee arthroplasty.[109,133–140] In a pilot study[141] among women after an ACL reconstruction, graded-exposure therapy led to decreases in fear about specific functional tasks (eg, jumping, hopping, pivoting) but not global changes in injury-related fear (ie, decreases on the Tampa Scale of Kinesiophobia-11). Unfortunately, no authors since 2012 have demonstrated the effectiveness of graded activity in reducing pain-related avoidance behaviors compared with therapeutic exercise as the standard of care.[109] Prospective studies are needed to systematically determine the effects of graded-exposure therapy on risk behaviors, psychological stress related to activities that load the knee, and adaptive behaviors against reinjury.

Dissenting Opinion. The language of the recommendation is too strong. Many patients experience injury-related fear after an ACL reconstruction, which increases the risk of secondary ACL injury. Although graded-exposure therapy may be beneficial for patients after an ACL reconstruction, we lack sufficient evidence to integrate it into the rehabilitative care of these patients. Specifically, it remains unclear if graded-exposure therapy offers a clinically meaningful effect on injury-related fear, kinesiophobia, or, most importantly, the risk of secondary injury.

9. Cognitive-behavioral counseling should be considered to promote patient engagement with therapies and exercise, reinjury prevention, and management and improvement of overall health and wellness after ACL injury or reconstruction

Cognitive-behavioral therapy is a treatment approach that focuses on efforts to change thinking patterns to overcome (1) flawed or nonhelpful ways of thinking, (2) learned patterns of unhelpful behaviors, and (3) barriers to coping with psychological problems. A variety of strategies are used to

a. Recognize one's distortions in thinking that lead to problems,
b. Improve understanding of motivation and behavior of others,
c. Problem solve to better cope with stress, and
d. Increase confidence in personal abilities.

These strategies include learning to calm oneself and relax the body. In addition, people may use role play to prepare for difficult interactions with others and face fears instead of avoiding them. Cognitive-behavioral therapy

helps individuals to problem solve and positively change behaviors in real-life situations. This comprehensive therapy is administered by trained, certified mental health specialists (ie, psychologists, psychiatrists, clinical social workers, professional counselors).[142] Investigators[143] have also employed other therapists trained by clinical psychologists to perform therapies at larger scales.

Cognitive-behavioral therapy may be helpful for some patients early after ACL injury or ACL reconstruction, but the evidence in this area is minimal. One aspect of cognitive-behavioral therapy, acceptance and commitment therapy, was beneficial in a case series of 4 athletes recovering from an ACL reconstruction (eg, improved acceptance of frustration, anxiety about or fear of reinjury, and motivation; better focused on the present; paying attention to the present during rehabilitation; and balanced values with committed action to recovery). Furthermore, in a pilot study[109] of 8 people with ACL reconstruction, a telephone-based program with various elements of therapy (eg, grounding and activity plan, monitoring self-talk, present mindedness, guided imagery) led to variable responses in kinesiophobia, knee-specific efficacy, and pain catastrophizing. These participants did not adopt these skills after the research intervention was completed. Therefore, this approach may work for some but not all individuals.

Cognitive-Behavioral Therapy Applications to Knee Symptom Management. The effects of long-term management of individuals with ACL injury or ACL reconstruction using cognitive-behavioral therapy are not yet known. Cognitive-behavioral therapy for people with knee OA improves physical performance, pain, the ability to cope with depression, anxiety, and pain catastrophizing when combined with interventions specific to the participants, such as pain psychology and weight management.[144,145] Cognitive-behavioral therapy can be effectively administered via the internet to reduce depression and improve self-efficacy, joint symptoms, and physical function among people with knee OA.[146] Unfortunately, it is unclear whether in-person or other methods of cognitive-behavioral therapy delivery influence the effectiveness of the therapy on outcomes. Additional research is needed to determine the optimal cognitive-behavioral therapy to improve function and quality of life and promote healthy engagement in regular physical activity after an ACL injury. Moreover, additional research is needed to determine which patients may respond best to cognitive-behavioral therapy, whether cognitive-behavioral therapy is more effective after injury or ACL reconstruction, and during which window of time the greatest effects on outcomes are produced with this therapy.

Dissenting Opinion. The language of the recommendation is too strong. There is a theoretical basis for this recommendation and evidence that cognitive-behavioral counseling has been effective for patients with acute and chronic musculoskeletal conditions. Cognitive-behavioral counseling may be beneficial for many aspects of care for a patient after an ACL injury. However, we lack sufficient evidence that cognitive-behavioral counseling will benefit this patient population, especially if a goal is reinjury prevention.

10. Patients should be monitored regularly after an ACL injury using a comprehensive approach, including patient-reported outcomes, performance-based outcomes, and measures of disease progression

No standard list of recommended patient-reported outcomes has been compiled for individuals after an ACL injury to monitor recovery, limiting evaluation of treatment effects and informed modifications to treatment plans. Incorporating outcomes from key experiential domains relevant to people with a history of ACL injury could help guide (1) return-to-sport decision-making and (2) treatments and approaches focused on slowing or halting the progression of OA. Domains that affect the quality of life include pain and other symptoms, function, fatigue, sleep, psychological factors, fear of movement, stress, depression, anxiety, and physical activity levels. Therefore, monitoring self-reported physical and mental health is an essential element of care to achieve treatment goals. Relevant measures commonly used in orthopaedic or rheumatology research for people with an ACL injury are presented in Table 1. Measures previously tested and used in populations with ACL injuries are listed as "recommended." Given the existing link between ACL injury and the future development of OA, measures that have been tested in populations with OA may also add value to the clinical assessment.

Objective measures from 6 domains provide complementary insight into patient-reported outcomes as part of the overall understanding of a patient's risk for knee OA after ACL injury: (1) clinical impairment related, (2) modifiable lifestyle related, (3) functional performance, (4) gait biomechanics, (5) imaging, and (6) biomarkers. These outcomes range from clinically accessible techniques that can easily be incorporated into the clinic to outcomes that provide insight into disease pathogenesis that are currently limited to a research setting (Table 2).

11. Use a multifaceted return-to-sport test battery to inform a shared decision involving all stakeholders (eg, patient, parents, health care team, and coach) when determining readiness to return to play

One of 4 adolescents and young adults who return to cutting and pivoting sports after an ACL injury will sustain a second ACL injury.[183] The risk for a second ACL injury in young athletes who return to sport after an ACL injury is 30 to 40 times greater than that for their uninjured peers.[183] A second ACL injury leads to far worse outcomes than the first ACL injury, including twice the risk of having below-normal knee function or developing knee OA.[184]

Current evidence-based return-to-sport criteria include benchmarks of quadriceps muscle strength, performance-based metrics such as single-legged hop tests, and patient-reported outcomes of subjective knee function.[36,185–187] Passing a return-to-sport test battery reduces the risk of an ACL or meniscal injury by more than 84%.[48,188] In contrast, failing to meet return-to-sport criteria is associated with a 4 times greater risk for sustaining an ACL graft rupture.[76] Quadriceps strength may be the most important criterion for predicting the reinjury risk.[48] Despite evidence that passing return-to-sport criteria reduces the reinjury risk, only 14% of patients met the recommended criteria for strength tests,

Table 1. Recommendations for Patient-Reported Outcomes Domains and Example Measures

Domain	Example Measure	No. of Items	Tested in Patients With ACL Injury?	Recommended or Suggested[a]
Pain/symptoms	NRS: pain[147,148] (ask separately at tibiofemoral and patellofemoral joints)	2	Yes	Recommended
	IKDC: Symptoms[149]	7	Yes	Recommended
	KOOS: Pain subscale[150–152]	9	Yes	Recommended
	KOOS: Symptoms subscale[150–152]	7	Yes	Recommended
Function	KOOS: Physical Function Short Form[152,154]	7	Yes	Recommended
	IKDC: Sports Activities[149]	10	Yes	Recommended
	IKDC: Function[149]	2	Yes	Recommended
	KOOS: Activities of Daily Living subscale[150–152]	17	Yes	Recommended
	KOOS: Sports and Recreation subscale[150–152]	5	Yes	Recommended
Fatigue	Stanford NRS fatigue[155]	1	No, used in OA	Suggested
	Fatigue: Perceived scale of exertion[156]	1	Yes	Recommended
	PROMIS: Fatigue[157]	7	No, used in OA	Suggested
Sleep	PROMIS-Sleep Disturbance Short Form[158]	8	No, used in OA	Suggested
Psychological	Anterior Cruciate Ligament Return to Sport After Injury[132]	12	Yes	Recommended
Fear of movement	Brief Fear of Movement Scale for osteoarthritis[158]	6	No, used in OA	Suggested
	Tampa Scale of Kinesiophobia-11[159]	11	Yes	Recommended
Stress	PROMIS Perceived Stress[157]	10	No, used in OA	Suggested
Depression	PROMIS Emotional Distress: Depression Short Form[157]	8	No, used in OA	Suggested
Anxiety	PROMIS Emotional Distress: Anxiety Short Form[157]	7	No, used in OA	Suggested
Physical activity	International Physical Activity Questionnaire Short Form[160]	7	Yes	Recommended
	Tegner Activity Scale[161]	1	Yes	Recommended
	Marx Activity Scale[162]	4	Yes	Recommended
Quality of life	KOOS: QOL subscale[150–152]	4	Yes	Recommended
Global rating of health	Health Status Questionnaire: self-rated general health[163]	1	No, used in OA	Recommended

Abbreviations: ACL, anterior cruciate ligament; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; NRS, numeric rating system; OA, osteoarthritis, PROMIS, Patient-Reported Outcomes Measurement Information System; QOL, quality of life.

[a] Measures previously tested and used in ACL-injured populations are listed as recommended.

Table 2. Recommendations for Objective Outcome Domains and Example Measures Assessed in Clinical or Research Settings

Domain	Example Measures	Research Only	Tested in Patients with ACL Injury?	Recommended or Suggested[a]
Clinical examination features	Joint line tenderness[164]		No, used in OA	Suggested
	Crepitus[165]		No, used in OA	Suggested
	Sweep/bulge test for joint effusion[166]		Yes	Recommended
	Joint alignment		Yes	Recommended
Modifiable lifestyle related	Body mass index[167]		Yes	Recommended
	Waist circumference		Yes	Recommended
	Fat mass (eg, dual-energy x-ray absorptiometry)		Yes	Recommended
	Physical activity (eg, step counts, % time moderate-vigorous activity)[168]	Yes	Yes	Recommended
Functional performance	Single-legged hop test[169]		Yes	Recommended
	Star Excursion Balance Test[170]		Yes	Recommended
	Chair stand test[171]		Yes	Recommended
	Walking speed test[172]		Yes	Recommended
	Muscle function (eg, isometric strength)[39]		Yes	Recommended
Gait biomechanics	Vertical ground reaction force[173]	Yes	Yes	Recommended
	Knee abduction moment[174]	Yes	Yes	Recommended
	Spatiotemporal measures[175]	Yes	Yes	Recommended
Imaging	Radiograph (eg, Kellgren-Lawrence, joint space width)[176,177]		Yes	Recommended
	Semiquantitative MRI (eg, whole-organ MRI score, Anterior Cruciate Ligament Osteoarthritis Score)[178]	Yes	Yes	Recommended
	Quantitative morphological MRI (eg, cartilage thickness, effusion-synovitis volume, bone marrow lesion volume)[179]	Yes	Yes	Recommended
	Quantitative Compositional MRI (eg, T1ρ, T2, dGEMRIC)[180]	Yes	Yes	Recommended
Biomarkers	Cartilage metabolism (eg, COMP, C2C, CPII)[181]	Yes	Yes	Recommended
	Inflammation (eg, IL-6, TNF-α)[182]	Yes	Yes	Recommended

Abbreviations: ACL, anterior cruciate ligament; COMP, cartilage oligomeric matrix protein; CPII, type 2 collagen synthesis C-propeptide; C2C, cleavage of type II collagen; dGEMRIC, delayed gadolinium-enhanced MRI of cartilage; MRI, magnetic resonance imaging; OA, osteoarthritis.

[a] Measures previously tested and used in ACL-injured populations are listed as recommended.

hop tests, and patient-reported outcomes after medical clearance to return to activity at approximately 8 months postoperatively.[36] Hence, some individuals may not meet the criteria at a pivotal moment in their return to activity.

Time since ACL reconstruction should not be the sole determinant of return-to-sport readiness.[189] It is, however, a relevant factor, as early return to sport is associated with a greater risk of reinjury.[48,190] For example, returning to sport before 9 months after an ACL reconstruction increased the risk for secondary injury.[48,190] Thus, return-to-sport testing should be coupled with assessing the time since ACL reconstruction to ensure appropriate knee function and biological healing. Other factors such as patient age, graft type, and concomitant injury may affect the timing of readiness for return to sport.[191,192] Furthermore, preliminary evidence[127,193,194] suggests that psychological readiness, kinesiophobia, and asymmetric biomechanical movement patterns may also be linked to the reinjury risk after returning to sport and thereby warrant assessment. As a result, clinicians should share decisions regarding return-to-sport readiness with the patient, parents of adolescents, medical team, and coaches based on functional return-to-sport testing, time since ACL reconstruction, and individual patient factors to minimize the secondary knee injury risk.

12. Implement a multifaceted preventive training program that includes strategies to improve agility, balance, flexibility, strength, and movement quality to reduce the risk of secondary injury

Several consensus statements and clinical practice guidelines, involving athletic training,[195] physical therapy,[196] the International Olympic Committee,[197] and the Osteoarthritis Action Alliance,[198] recommend primary injury-prevention programs. Although the bulk of the existing injury-prevention literature focuses on primary injury prevention, the continued increase in youth and adolescent ACL injuries creates a growing population needing secondary prevention strategies to prevent reinjury and OA.[183,199]

Primary preventive training programs that optimize prophylactic benefits are multicomponent exercise programs incorporating agility, balance, flexibility, plyometrics, and strength exercises.[200] Which of the exercise subtypes is most influential in reducing injury risk and rate is unknown, yet the combination of various exercises appears important. Also, participants should receive continual feedback regarding proper technique, such as reminders to bend at the knees and hips, land softly, keep the knees over the toes, and avoid dynamic knee valgus (ie, knees caving inward).[201–204] These programs aim to improve lower extremity biomechanics and elements of neuromuscular control and are strongly recommended to reduce lower extremity injury risks and rates.[196–198]

To optimize widespread adoption, ACL injury-prevention programs are typically 10 to 20 minutes long and used as a preactivity warm-up.[205] When possible, advocates for preventive training programs should work with coaches, team captains, or other stakeholders. They should review the stakeholder's existing warm-up program to determine if minor adjustments could be made to ensure that it incorporates key exercise types. Existing resources, such as the "Remain in the Game: A Joint Effort" tool kit (remaininthegame.org), are available to help health professionals and coaches develop tailored programs for their athletes. Stakeholders should consider factors such as the type of sport, level of competition, and physical ability of the athletes to tailor the program and appropriately challenge them if needed. Preventive training programs can reduce the risk of primary ACL injuries by 53%.[206] Based on the success of primary ACL injury-prevention programs, similar prevention programs to maintain and enhance recovery during postoperative rehabilitation are also likely to reduce the incidence of second ACL injury.

Secondary ACL injury-prevention programs are effective in altering lower extremity biomechanics in those with an ACL reconstruction.[207–209] Similar to primary ACL injury-prevention programs, the successful alteration of lower extremity biomechanics may lead to a reduced incidence of second ACL injury. During a 2-year intervention with 1435 athletes, those with a self-reported history of ACL injury in the control group had an ACL reinjury rate 5 times greater than that of athletes with a self-reported history of ACL injury who completed a preventive training program. Furthermore, no athlete with a prior ACL injury who completed the preventive training program sustained a noncontact reinjury.[210] In 2 other studies,[211,212] the incidence of second ACL injury was only 2.5% among male and 23% among female athletes who performed a secondary prevention program, compared with an incidence rate of 30% for a second ACL injury based on earlier publications.[48,56,183,213,214] Hence, secondary injury-prevention programs may be effective in male athletes but less so in female athletes. However, female athletes in this cohort had only a 14% incidence of contralateral second ACL injury, which is a promising finding. Across all studies[210–212] examining preventive training exercises in those with an ACL reconstruction, the incidence of second ACL injury was 8%. These data provide initial evidence to support the recommendation of implementing preventive training programs to reduce the risk of secondary ACL injury; still, future research is needed in this area.

Dissenting Opinion. In theory, this is a great recommendation. A multicomponent training program is important. Nonetheless, the authors of 2 systematic reviews[215,216] concluded that multicomponent programs were effective but raised concerns that balance may not be a beneficial component and that time previously dedicated to balance activities may be more beneficial if used for technique training, strengthening, or another component.

13. Organizations should optimize socially supportive environments for athletes, service members, employees, providers, families, and caregivers. This can be achieved by recognizing and providing support for psychosocial stressors during the rehabilitation process, including injury-related stigma, uncertainty about return to activity, and threats to personal identity

People with a knee injury who return to activity sooner than they are psychologically ready may experience reinjury, injury to different body parts, anxiety, fear, depression, demotivation, and a decrease in sport performance.[217–219] Extrinsic motivations such as "feeling

pressured by their coach to return" or feeling "guilty for letting others down if they do not return" were associated with negative psychological outcomes including increased worry and concern.[220] Threats to successful rehabilitation after an injury involve fear and lack of confidence in returning to activity (eg, sport or active military duty) and unrealistic expectations of one's capabilities, support, and motivation (eg, to regain previous performance standards, to get back in the fight).[221,222] Similarly, injured soldiers who return to duty too quickly because of a strong sense of personal commitment and expectations to do so may endanger war fighter proficiency, the safety and effectiveness of the unit, and their mission.[223,224] Hence, we need to educate patients about normal injury recovery times and standardize communication from surgeon to therapist to other key stakeholders to ensure that everyone "remains on the same page" regarding prognosis expectations.[225]

Social support and perceived social support influence injury rehabilitation through a buffering effect that "protects" an individual from the detrimental effects of injury-related stressors involving rehabilitation.[226] In addition, social support has a positive effect on an athlete's adherence to an injury rehabilitation program.[227–230] Suitable support structures, such as trust in a health care provider, trust in a rehabilitation program, and a facilitative environment,[227,229,230] are crucial in optimizing adherence during injury rehabilitation. Although emotional support is most effective when provided by family and friends, task support may be most effective when provided by a rehabilitation clinician, such as a physical therapist or AT.[228] Rehabilitation clinicians can serve a patient's psychosocial needs using system-level task support and comprehensive strategies, including structured goal setting, action planning, and preoperative modeling.[231,232]

Organizational leadership should recognize the personal social stigma associated with injury, including the sense of burden placed on the team.[233,234] It may be beneficial for organizations to better normalize the rehabilitation experience by including teammates in the postinjury and rehabilitation experience and increase structural support via scheduling services, because executive function and mental processes are negatively affected during injury and rehabilitation.[235–237] Further exploration of the role of organizational support in reducing the risk of OA after an injury would also be helpful.

14. Use technology to enable an individual with a knee injury to monitor physical and psychological well-being over time, access evidence-based educational materials developed specifically for their needs, and engage in health promotion

In recent years, technology-driven tools have been developed for primary musculoskeletal injury prevention, promotion of health behaviors, and assessment of health-related outcomes among a broad spectrum of demographic groups.[238–240] For example, the "Walk With Ease" program for individuals with OA[241–243] leverages a web-based assessment tool to deliver a hybrid self-organized and community-based walking intervention to reduce OA-related symptoms and improve overall health. Similarly, the Osteoarthritis Action Alliance developed and disseminated the "Remain in the Game" web-based platform to provide educational materials and evidence-based knee-injury risk-mitigation strategies to active individuals. Unfortunately, these interventions do not address the needs of patients who have sustained a knee injury. Importantly, they are not delivered using methods preferred by the young and active individuals who are most likely to experience an ACL injury (eg, mobile applications and commercially available wearable technology).[244,245]

Mobile and web-based platforms can measure physical activity and biomechanical outcomes, particularly when linked to wearable technology. Furthermore, these platforms may inform individuals about their progress toward achieving short- and long-term goals.[244–246] Regrettably, we lack a comprehensive technological solution that integrates all the aforementioned recommendations about the support and educational needs of individuals who have sustained a knee injury. Mobile applications, wearable technology, and web-based education that address areas relevant to this population (eg, see the physical, psychological, and social recommendations) may assist in monitoring patient progress or provide education, monitoring, activity promotion, social support, and alerts. A mobile application and potentially commercially available wearable sensors (eg, smart watches, activity trackers) should be used to collect information regarding the characteristics (eg, frequency, intensity, and duration) of exercise with which an individual participates, knee-related function or other patient-reported outcomes of interest, and symptoms during activities of daily living and exercise. A mobile application and potentially commercially available wearable sensors should also be leveraged to deliver individualized and self-driven exercise interventions to maintain knee and overall health after an individual's completion of formalized rehabilitation.[239,240] Moreover, mobile applications can provide a portal for chat or other forms of engagement with a community of individuals experiencing a similar recovery process. Finally, mobile notifications should alert an individual when the patient-reported outcome measures indicate that engagement with a health care provider is indicated. This mobile application could also provide links to health care providers in the local area to reduce user friction with the health care system.

15. Practitioners ought to consider both the ethics and efficacy of how and what technology is adopted for monitoring health outcomes and OA prevention after joint injury

Considering the pace of technological health and wellness solutions entering the marketplace, a "buyer-beware" mentality is wise for both patients and practitioners. In addition, the development and implementation of technology-based solutions need to occur in a manner that allows a user to maintain control of the data and the interaction with the new technology. For example, the development of mobile applications to deliver rehabilitation information and increase adherence to exercise should be engaged wisely. Much of our current technology has been designed to use cognitive-behavioral prompts (ie, "nudges") to users toward certain behaviors and adherence to intervention goals.[247,248] Prompts can create adherence, but when misused, they can lead to the unhealthy use of technology and fail to benefit the patient. The potential for

technology to provide great access to care and support healthy lifestyles is ideal. As with in-person treatment, it is often prudent to seek the services of competent professionals.

Dissenting Opinion. The recommendation may lack the specificity needed to inform practitioners. Monitoring of health outcomes is different from using technology to promote adherence to or participation in injury prevention. The safety of personal health information on any system should be protected per standard protocols. Existing protocols are not fully secure from spyware and phishing attacks. The use of electronic health records has put all patient information at risk.

Educative nudges[249]—similar to those used in technology for ACL injury prevention—act to affect people's choice making by engaging their insightful abilities. Recipients are likely to receive informational materials with this expectation, and they would not expect to be affected in other ways. The ethical concern of reminding patients with educative nudges has not been substantiated.[249] The potential for benefit from this technology and virtual visits is enormous, with minimal risk or hazard.[247,248]

16. An interdisciplinary, coordinated, patient-centered care strategy is advised to comprehensively address the needs of patients with a history of knee injury

Clinicians need to recognize the multifaceted nature of a patient's state. An ideal strategy to implement the aforementioned recommendations to address a patient's needs may be to deploy a personalized, interdisciplinary comprehensive approach that uses technology-driven solutions. Clinicians who manage patients with chronic symptoms (eg, OA) have increasingly adopted coordinated interdisciplinary care models to optimize outcomes.[250–253] For example, the Osteoarthritis Chronic Care Program includes exercise and occupational therapy, psychological support, and medical management for Australians with hip or knee OA.[252,254] Many people who complete the program become unwilling to undergo knee surgery, partially because of improved knee pain and function. These unperformed arthroplasties may contribute to saving greater than $1 million per year at some clinical sites.[252,254] Despite established coordinated care models for certain chronic conditions, testing of coordinated care strategies tailored to younger people with chronic symptoms after an ACL reconstruction is needed. For example, these programs could offer this population

a. Anti-inflammatory medications (as needed),
b. Adaptive supervised rehabilitation with a home exercise program and injury-prevention exercises,
c. Education to maintain or improve self-efficacy and promote adherence and stress management, and
d. Social support.

Furthermore, coordinated interdisciplinary care models could also be adapted for when a person first engages with the health care team after an ACL injury to optimize outcomes. Members of the coordinated care team may include (but are not limited to) primary care physicians, orthopaedic surgeons, physical therapists, ATs, psychologists or mental health consultants, strength and conditioning specialists, and nutritionists. Despite the need for more evidence to support these types of programs in this population, the low risk and intuitive advantage of these strategies make them appealing.

DISCUSSION

These consensus-based recommendations provide clinicians with secondary prevention strategies intended to reduce the risk of OA among patients after an ACL injury. We acknowledge the dearth of high-quality evidence to inform some of these recommendations and offer dissenting opinions to facilitate discussion. These consensus recommendations are not a formal clinical practice guideline based on a synthesis of high-quality evidence. Instead, this document reflects information synthesized from an interdisciplinary group of experts based on the best available evidence from the literature or personal experience. Task group members often weighed the level of evidence with the perceived risk-to-benefit ratio of advocating (or not advocating) for these recommendations. Members were predominately based in the United States, which may influence how clinicians outside the United States interpret the applicability of these recommendations to their clinical practice. We hope these recommendations foster more discussion on how we can help ensure the long-term wellness of people after joint injuries in general, not just ACL injuries. We trust that these recommendations will spark discussion about what patients need to know to be informed consumers in a health care system. We acknowledge the need for more high-quality research studies to shape future recommendations, and we hope this document raises awareness among clinicians and researchers so that they will take steps to mitigate the risk of OA after an ACL injury.

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