Exercise-Based Knee and Anterior Cruciate Ligament Injury Prevention

Title Page

Exercise-Based Knee and Anterior Cruciate Ligament Injury Prevention
Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy

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- Academy of Orthopaedic Physical Therapy
- American Academy of Sports Physical Therapy
- clinical practice guidelines
- exercise-based prevention
- ICD
- ICF
- knee

Abstract

The Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy have an ongoing effort to create evidence-based clinical practice guidelines (CPGs) for orthopaedic and sports physical therapy management and prevention of musculoskeletal impairments described in the World Health Organization's International Classification of Functioning, Disability and Health (ICF). This particular guideline focuses on the exercise-based prevention of knee injuries and provides an update on the 2018 guidelines.
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Summary of Recommendations*

Review the Evidence in the Scientific Literature for Exercise-Based Knee Injury Prevention Programs

[A] Clinicians should recommend use of exercise-based knee injury prevention programs in athletes for the prevention of knee and anterior cruciate ligament (ACL) injuries. Programs for reducing all knee injuries include 11+ and FIFA 11, HarmoKnee, and Knäkontroll; and those used by Emery and

Meeuwisse,[7] Goodall et al,[9] Junge et al,[16] LaBella et al,[18] Malliou et al,[20] Olsen et al,[24] Pasanen et al,[26] Petersen et al,[27] and Wedderkopp et al.[33] Programs for reducing ACL injuries include HarmoKnee, Knäkontroll, Prevent Injury and Enhance Performance (PEP), and Sportsmetrics™; and those used by Caraffa et al,[6] Heidt et al,[11] LaBella et al,[18] Myklebust et al,[22] Olsen et al,[24] and Petersen et al.[27]

[C] Clinicians may recommend the use of an exercise-based neuromuscular training program in the late phase of ACL reconstruction rehabilitation for the secondary prevention of ACL injuries

Identify Exercise-Based Knee Injury Prevention Programs that are Effective for Specific Subgroups of Athletes

[A] Clinicians, coaches, parents, and athletes should implement exercise-based knee injury prevention programs prior to practices/training sessions or games in women athletes to reduce the risk of ACL injuries, especially in athletes younger than 18 years of age. Programs that should be implemented include PEP, Sportsmetrics™, Knäkontroll, HarmoKnee, and those used by Olsen et al[24] and Petersen et al.[27]

[A] Soccer players, both women and men, should use exercise-based knee injury prevention programs to reduce the risk of severe knee and ACL injuries. Programs that could be beneficial for preventing severe knee injuries include PEP, Knäkontroll, and HarmoKnee. Programs that could be beneficial for specifically preventing ACL injuries include the 11+, Sportsmetrics™ and the program used by Caraffa et al[6].

[B] Men and women team handball players, particularly those 15 to 17 years of age, should implement exercise-based knee injury prevention programs. Programs that could be beneficial for preventing knee injuries include those used by Olsen et al[24] and Achenbach et al.[2]

Describe the Evidence for Components, Dosage, and Delivery of Exercise-Based Knee Injury Prevention Programs

[A] Exercise-based knee injury prevention programs used for women should incorporate multiple components, proximal control exercises, and a combination of strength and plyometric exercises.

[A] Exercise-based knee injury prevention programs should involve training multiple times per week, training sessions that last longer than 20 minutes, and training volumes that are longer than 30 minutes per week.

[A] Clinicians, coaches, parents, and athletes should start exercise-based knee injury prevention programs in the preseason and continue performing the program through the regular season.

[A] Clinicians, coaches, parents, and athletes must ensure high compliance with exercise-based knee injury prevention programs, particularly in women athletes.

[B] Exercise-based knee injury prevention programs may not need to incorporate balance exercises, and balance should not be the sole component of a program.

Provide Suggestions for Implementation of Exercise-Based Knee Injury Prevention Programs

[A] Clinicians, coaches, parents, and athletes should implement exercise-based knee injury prevention programs in all young athletes, not just those athletes identified through screening as being at high risk for ACL injury, to optimize the numbers needed to treat while reducing cost.

[A] For the greatest reduction in future medical costs and prevention of ACL injuries, osteoarthritis, and total knee replacements, clinicians, coaches, parents, and athletes should encourage implementation of

exercise-based ACL injury prevention programs in athletes 12 to 25 years of age and involved in sports with a high risk of ACL injury.
[B] Clinicians, coaches, parents, and athletes should support implementation of exercise-based knee injury prevention programs led by either coaches or a group of coaches and medical professionals.

List of Abbreviations

11+
an injury prevention program developed originally by the FIFA Medical Assessment & Research Center (F-MARC) (previously known as FIFA 11+)
ACL
anterior cruciate ligament
AE
athlete-exposure
AMSTAR
A Measurement Tool to Assess Systematic Reviews
APTA
American Physical Therapy Association
CI
confidence interval
CPG
clinical practice guideline
EMG
electromyography
FIFA
Fédération Internationale de Football Association (international soccer governing body)
FIFA 11
also known as "the 11," an injury prevention program developed originally in association with the medical committee of FIFA and the predecessor to the 11+
ICD
International Classification of Diseases
ICF
International Classification of Functioning, Disability and Health
JOSPT
Journal of Orthopaedic & Sports Physical Therapy
KLIP
Knee Ligament Injury Prevention program
NMT
neuromuscular training
PEDro
Physiotherapy Evidence Database
PEP
Prevent Injury and Enhance Performance injury prevention program
RCT
randomized controlled trial
RR
Relative Risk

RTS
return to sport
SIGN
Scottish Intercollegiate Guidelines Network

Introduction

Aim of the Guideline

The Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy have an ongoing effort to create evidence-based clinical practice guidelines (CPGs) for orthopaedic and sports physical therapy management and prevention of musculoskeletal impairments described in the World Health Organization's *International Classification of Functioning, Disability and Health* (ICF).[1] This particular guideline focuses on the exercise-based prevention of knee injuries. *Exercise-based prevention* was defined as an intervention requiring the participant(s) to be active and move. This could include physical activity; strengthening; stretching; neuromuscular, proprioceptive, agility, or plyometric exercises; and other training modalities, but excludes passive interventions such as bracing or programs that only involve education. *Knee injuries* were defined as any knee joint pathology including damage to the joint (patellofemoral and/or tibiofemoral), ligaments, meniscus, or patellar tendon. The recommendations can be followed and implemented by athletes, coaches, health and fitness professionals, athletic trainers, physical therapists, physicians, surgeons, and other clinicians.
The objectives of this CPG are as follows:
Review the evidence in the scientific literature for exercise-based knee injury prevention programs.
Identify exercise-based knee injury prevention programs that are effective for specific subgroups of athletes.
Describe the evidence for the components, dosage, and delivery of exercise-based knee injury prevention programs.
Provide suggestions for the implementation of exercise-based knee injury prevention programs.
Create a reference publication for athletes, coaches, parents, students, interns, residents, fellows, athletic trainers, orthopaedic and sports physical therapy clinicians, academic instructors, clinical instructors, and physicians and surgeons in orthopaedics and sports regarding the best current practice of exercise-based knee injury prevention programs.

Statement of Intent

These guidelines are not intended to be construed or to serve as a standard of medical care. Standards of care are determined on the basis of all clinical data available for an individual athlete/patient and are subject to change as scientific knowledge and technology advance and patterns of care evolve. These parameters of practice should be considered guidelines only. Adherence to them will not ensure a successful outcome in every athlete or patient, nor should they be construed as including all proper methods of care or excluding other acceptable methods of care aimed at the same results. The ultimate judgment regarding a particular injury prevention plan, clinical procedure, or treatment plan must be made based on experience and expertise in light of the presentation of the athlete or patient, the available evidence, available diagnostic and treatment options, and the athlete or patient's values, expectations, and preferences. However, when providing care for athletes/patients, we suggest that

significant departures from accepted guidelines should be documented in the athlete/patient's medical records at the time the relevant clinical decision is made.

Scope

The aims of the revision were to provide a concise summary of the evidence published since the original guildeline in 2018. Where appropriate the revision aimed to update or revise recommendations and evidential support based on the available literature.

Methods

The Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy appointed content experts with relevant physical therapy, medical, and surgical expertise as developers and authors of the CPG for exercise-based knee injury prevention. These experts were given the task of conducting a review of the literature and describing the interventions and evidence for exercise-based knee injury prevention. The authors declared relationships and developed a conflict management plan, which included submitting a Conflict of Interest form to the Academy of Orthopaedic Physical Therapy, APTA, Inc. Funding was provided by the Academy of Orthopaedic Physical Therapy and American Academy of Sports Physical Therapy, and by the APTA to the CPG development team for travel and expenses for CPG development training. The CPG development team maintained editorial independence.

With the assistance of a research librarian (T.H.), the authors systematically searched PubMed, Scopus, SPORTDiscus, CINAHL, and the Cochrane databases for relevant articles. Literature searches were performed on October 23, 2020 and updated on February 18, 2022. The searches included articles published from 2017 to February 2022 to cover the period since the previous CPG.

Reference lists of included sources were hand searched for additional articles not identified in the searches (see **APPENDIX A** for full search strategies and **APPENDIX B** for search dates and results, available at www.orthopt.org).

Inclusion and exclusion criteria used to select relevant articles were as follows.

Inclusion Criteria

Exercise-based knee injury prevention

Studies needed to expressly state that knee injuries of any kind were the specific target of the program and outcome measure of the study.

Exercise-based prevention was defined as an intervention requiring the participant to be active and move his or her body. This could include physical activity; strengthening; stretching; neuromuscular, proprioceptive, agility, or plyometric exercises; and other training modalities, but excluded passive interventions such as bracing or programs that only involved education.

Knee injuries were defined as any knee joint pathology including damage to the joint (patellofemoral and/or tibiofemoral), ligaments, meniscus, or patellar tendon.

Articles that focused on preventing knee injuries as a whole were included, but so too were articles focused on only one type of knee injury (e.g. anterior cruciate ligament [ACL] injuries or patellofemoral pain). This CPG delineates between evidence related to ACL injuries and all knee injuries.

Mechanism of injury included both contact (injuries as a result of collision with another person or object) and noncontact (injuries that do not involve another individual or object).[8] This CPG discusses contact and noncontact injuries together, unless specifically noted in the text.

Meta-analyses

Systematic reviews
Randomized controlled trials (RCTs)
Cost-effectiveness studies
High-level cohort studies (critical appraisal score on the Scottish Intercollegiate Guidelines Network [SIGN] checklist of 5 or greater)
Published in a peer-reviewed journal
Able to access full-text article
Published and accessible in English

Exclusion Criteria

Injury prevention programs aimed at preventing all lower extremity injuries
Injury prevention programs aimed at preventing lower extremity injuries other than knee injuries (e.g. ankle injury prevention programs)
Injury prevention programs aimed at modifying risk factors for knee injuries (e.g. modifying peak knee abduction moment)
Non–exercise-based interventions (e.g. prophylactic bracing)
Case series
Case-control studies
Case studies
This guideline focuses on exercise-based knee injury prevention programs, and excludes broader programs aimed at preventing lower extremity injuries. Lower extremity injury prevention programs target a wide range of pathologies, thus selecting different exercises or focusing athlete feedback on joints other than the knee. Further, mechanisms of prevention may also differ. Programs targeting risk factors for knee injuries (e.g, programs focused on modifying knee biomechanics during jump landing) were also excluded from this CPG. There are a number of modifiable and nonmodifiable risk factors for knee injuries. However, the magnitude of each risk factor for an athlete can be dependent on many other variables. For example, hormonal changes as a result of menstruation may affect women but not men.[10] Similarly, asymmetries in jump landing have been associated with knee injuries in women[12] but not, to date, in men. As an international group of experts in prevention, familiar with the prevention literature as a whole as well as that specific to knee injuries, the authors felt that these were appropriate restrictions.
Components of training programs were defined as different exercise approaches involved in the prevention programs. For example, a program that only involved balance exercises was considered to only have 1 component, whereas a program that involved strengthening and plyometric exercises was considered to have multiple components. Common components include flexibility, strengthening, plyometrics, balance, and agility.
One author (D.S.) screened articles for full-text availability and for publication in English and in peer-reviewed journals. Two authors (A.A. and C.D. or R.K..) then independently screened articles for inclusion based on title and abstract. The authors then discussed their findings. Any article that clearly did not meet inclusion criteria based on title and abstract was excluded at this point, and the full text of any article that the authors were unsure of or that seemed to clearly meet inclusion criteria was then reviewed. If a CPG author was the author of a study eligible for potential inclusion, that author did not participate in the inclusion/exclusion decision for that paper. Full-text reviews were performed independently by two authors (A.A. and C.D. or R.K). The authors met to review their findings, and all disagreements on inclusion/exclusion were resolved by discussion as well as consultation with two other authors (A.G. and D.L.). Consensus was reached on all articles (see **APPENDIX C** for the flow chart of

articles and **APPENDIX D** for the citations of articles included in this guideline, available at www.orthopt.org).

All authors were involved in the quality-assessment and data-extraction process. Two authors independently assessed the quality of each article. If a CPG author was the author of an included paper, they did not participate in the quality-assessment or data-extraction process for that paper. The A Measurement Tool to Assess Systematic Reviews (AMSTAR) tool was used to assess the quality of meta-analyses and systematic reviews.[29] The Physiotherapy Evidence Database (PEDro) scale was used to assess the quality of RCTs,[31] the SIGN checklist was used to assess the quality of cohort studies.[5] Reliability using the quality-appraisal tools was established in the majority of authors during the creating of the 2018 guidelines. Two new authors, who did not participate in the 2018 guideline, established reliability with the lead author through independently assessing and then discussing scoring of three papers. Discrepancies in quality ratings were resolved through discussion between the 2 authors, and when needed the lead author (A.A.) made a final decision. Studies that were authored by a reviewer were assigned to an alternate reviewer. Studies with a quality score less than 5 on any scale were considered low quality and were not used in the development of these guidelines[19] (see **APPENDIX E** for quality-assessment scores, available at www.orthopt.org). Recommendations were written based on the included articles and were agreed on by all authors. **APPENDICES A** through **G** are available on the CPG web page at www.orthopt.org.

This guideline was issued in 2022 based on the published literature up to January 2022. This guideline will be considered for review in 2027, or sooner if significant new evidence becomes available. Any updates to the guideline in the interim period will be posted on the Academy of Orthopaedic Physical Therapy website (www.orthopt.org).

Levels of Evidence

Articles were graded according to criteria adapted from the Centre for Evidence-based Medicine, Oxford, United Kingdom for diagnostic, prospective, and therapeutic studies.[5] One team of four authors (A.A., C.D, R.K., D.L.) came to consensus and assigned a level of evidence based on the quality assessment of each article, the entire author group then approved the decisions (see **APPENDICES F** and **G** for the evidence table and details on procedures used for assigning levels of evidence, available at www.orthopt.org). An abbreviated version of the grading system is provided below.

I	Evidence obtained from systematic reviews, high-quality diagnostic studies, prospective studies, or randomized controlled trials
II	Evidence obtained from systematic reviews, lesser-quality diagnostic studies, prospective studies, or randomized controlled trials (e.g. weaker diagnostic criteria and reference standards, improper randomization, no blinding, less than 80% follow-up)
III	Case-control studies or retrospective studies
IV	Case series
V	Expert opinion

Grades of Evidence

The authors developed recommendations based on the strength of evidence, including how directly the studies addressed exercise-based knee injury prevention programs. The strength of the evidence supporting each recommendation was graded according to the previously established methods and is

provided on the next page. In developing their recommendations, the authors considered the strengths and limitations of the body of evidence and the health benefits and risks of interventions.

Description of Guideline Review Process and Validation

Identified reviewers who are experts in knee injury prevention reviewed the CPG draft for integrity, accuracy, and to ensure that it fully represented the current evidence for the condition. The guideline draft was also posted for public comment and review on www.orthopt.org, and a notification of this posting was sent to the members of the Academy of Orthopaedic Physical Therapy, APTA, Inc. In addition, a panel of consumer/patient representatives and external stakeholders, such as coaches, athletes, parents, team organizers academic educators, clinical educators, physician specialists, and researchers, also reviewed the guideline. All comments, suggestions, and feedback from the expert reviewers, public, and consumer/patient representatives were provided to the authors and editors for consideration and revisions. Guideline development methods, policies, and implementation processes are reviewed at least yearly by the Academy of Orthopaedic Physical Therapy, APTA,'s ICF-Based Clinical Practice Guideline Advisory Panel, including consumer/patient representatives, external stakeholders, and experts in physical therapy practice guideline methodology.

GRADES OF RECOMMENDATION		STRENGTH OF EVIDENCE
A	Strong evidence	A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study
B	Moderate evidence	A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation
C	Weak evidence	A single level II study or a preponderance of level III and IV studies, including statements of consensus by content experts, support the recommendation
D	Conflicting evidence	Higher-quality studies conducted on this topic disagree with respect to their conclusions. The recommendation is based on these conflicting studies
E	Theoretical/foundational evidence	A preponderance of evidence from animal or cadaver studies, from conceptual models/principles, or from basic science/bench research supports the recommendation
F	Expert opinion	Best practice based on the clinical experience of the guidelines development team

Dissemination and Implementation Tools

In addition to publishing this guideline in the *Journal of Orthopaedic & Sports Physical Therapy* (*JOSPT*), it will be highlighted and posted on the CPG web page of the *JOSPT* and the Academy of Orthopaedic Physical Therapy, APTA, and APTA websites. These web pages have unrestricted public access. Implementation tools and associated implementation strategies that will be made available for athletes, coaches, patients, physicians, surgeons, clinicians, educators, payers, policy makers, and researchers are listed in **TABLE 1**.

TABLE 1
Planned Strategies and Tools to Support the Dissemination and Implementation of this Clinical Practice Guideline

Tool	Strategy

“Perspectives for Patients” and videos for clinicians, coaches, and athletes	Patient-oriented guideline summary available on www.jospt.org and www.orthopt.org (**FIGURES 1** and **2**, **TABLE 2**)
Mobile applications of guideline-based exercises for patients/clients, athletes, coaches, and health care practitioners	Marketing and distribution of app using www.orthopt.org
Clinician's quick-reference guide	Summary of guideline recommendations available on www.orthopt.org
Read-for-credit continuing education content	Continuing education content available for physical therapists and athletic trainers from JOSPT
Webinar-based educational offerings for health care practitioners	Guideline-based instruction available for practitioners on www.orthopt.org
Mobile and web-based applications for health care practitioner training	Marketing and distribution of app using www.orthopt.org
Non-English versions of the guidelines and guideline implementation tools	Development and distribution of translated guidelines and tools to JOSPT's international partners and global audience via www.jospt.org

Classification

The primary International Classification of Diseases-10th Revision (ICD-10) codes and conditions associated with exercise-based knee injury prevention are: **S83.2 Tear of the (medial) (lateral) meniscus of the knee**, **S83.4 Sprain and strain involving (fibular) (tibial) collateral ligament of knee**, **S83.5 Sprain and strain involving (anterior) (posterior) cruciate ligament of knee**, **S83.7 Injury to multiple structures of knee**, **S83.6 Sprain and strain of other unspecified parts of the knee**, and **M22.2 Patellofemoral disorders**.
The primary ICF activities and participation codes associated with exercise-based knee injury prevention are: **d410 Changing basic body positions**, **d450 Walking**, **d4552 Running**, **d4553 Jumping**, **d4559 Moving around**, **specified as direction changes while walking or running**, **d9200 Play**, **d9201 Sports**, and **d9202 Arts and culture**.

Organization of the Guidelines

Topics are arranged in relation to the CPG objectives. For each objective, the recommendations from the 2018 guideline are presented followed by a summary, including the levels of evidence, and synthesis of the new evidence. Based on this new evidence and evidence synthesis, the updated 2022 recommendations including grades are presented at the end of each objective.

Clinical Practice Guidelines

A summary of the studies included in this 2022 update are found in Table 2.

Table 2. Evidence Table

Article	Type of Study	Evidence Rating	Conditions	Sample Characteristics	Outcome Measures

			Inclusion	**Exclusion**		
Arundale 2018	Randomized Control Study	1	1) Three to nine months after unilateral ACL reconstruction 2) 80% quadriceps strength limb symmetry (QI), 3) Minimal effusion, no pain, full range of motion, and successful completion of a running progression	Athletes were excluded if they had a 1) concomitant >1 cm2 full thickness chondral defect (assessed via arthroscopy or MRI) or grade three ligamentous injury (example medial or lateral collateral ligament), 2) Previous ACL reconstruction or a history of major lower extremity injury or surgery to either limb 3) Had already returned to sport	N=40 n =20 Intervention group n =20 Control group Level I/II Men Athletes Age: 15-54yrs Mean Height: 1.79 +/- 0.07m Mean Weight: 85.39 +/- 9.32 (kg) Mechanism of Injury: 18 Contact and 22 Non-Contact Graft Type: 13 Allograft, 19 Hamstring Autograft and 8 BTB Autograft	**Primary:** Number of Athletes who returned to sport **Secondary:** Number of athletes who returned to preinjury level of sport and number of second ACL injuries
Johnson 2020	Randomized Control Study	1	1) Age 13-55 2) Planned to return to cutting/pivoting/jumping sport for more than 50hrs per year 3) No previous ACL injury 4) No history of major lower extremity injury/surgery	1) Not level 1 or 2 athlete 2) Previous ACL/Lower extremity injury 3) >9 months from ACLR 4) Continued impairments 5) Concomitant injuries	N=39 n=19 Intervention n=20 Control Level I/II Women athletes Height 1.65 +- 0.08m Graft Type: Patella tendon 16, Hamstring autograft 18, Allograft 5	**Primary:** Rate of second ACL injury in women athletes after ACLR **Secondary:** Rate of ipsilateral second ACL injury

Huang 2020	Meta-analysis	1	1) The intervention aimed to prevent ACL injury 2) The study recorded the incidence rate (IR) or other outcome data such as injury counts and athlete exposures (i.e., time at risk) that made it possible to calculate ACL IR for both the intervention and control groups were reported 3) The study used a prospective RCT or cluster-RCT design	1) Review articles 2) Editorials 3) Non full text articles such as lectures, commentaries, abstracts, case studies, or surgical techniques 4) Articles that were not peer reviewed or not written in English	8 studies n=13,562 Men and women with age ranges from 12-25.9 years playing soccer, handball, basketball, or volleyball.	**Primary:** ACL injury incidence rate **Secondary:** Incidence rate based on if an injury prevention program met NATA position statement recommendations
Olivares-Jabalera et al 2021	Systematic Review	1	1) Adult (16-40yo) soccer players, both men and women, of any level who have not suffered a severe injury in previous 2 years 2) Exercise or training-based interventions lasted at least 4 weeks, performed twice a week 3) Either contact or non-	1) Included different cohorts of athletes apart from football players 2) Included interventions performed with exogenous	N=29 n =6 Studies investigating exercise-based interventions on ACL injury rates n =23 Studies investigating	**Primary:** Effect of exercise-based interventions on ACL injury rate for adult football players **Secondary:** Effect of exercise-based interventions on modifiable risk factors for ACL

			contact ACL injury incidence or rate of injury 4) Test measurements evaluating any modifiable risk factor previously reported to have an influence in ACL injury 5) Randomized-controlled trials, Non-randomized studies and Single-arm studies	modalities or exercise-based interventions lasting less than 4 weeks 3) Did not explicitly report overall injury incidence of ACL type injuries 4) Had test measured evaluating non-modifiable risk factors 5) Were systematic reviews, meta-analysis, conference papers, book chapters or studies published in languages other than English	exercise-based interventions on modifiable risk factors for ACL injury Level I/II Athletes Age: 16-40yrs Study Types: 11 Parallel RCTs, 4 Cluster RCTs, 8 Non-RCTs and 6 Single-arm	injury for adult football players
Webster 2018	Meta-analysis	1	1) A meta-analysis of randomized controlled trials (RCTs) or prospective cohort studies that evaluated the effectiveness of an ACL injury prevention training program 2) Reported data on the incidence of ACL injuries 2) Written in English.	1) Systematic reviews that did not pool data or perform a meta-analysis 2) Narrative reviews or those without a search algorithm or failed to describe how studies were selected for the review 3) Reviews that evaluated	8 meta analysis N=40,003 in treatment groups N= 52704 in control groups Men and women athletes	**Primary:** Odds ratios with 95% CIs ACL injury **Secondary:** Odds ratios for ACL injuries in women and non-contact ACL injuries in women

				a general or sports injury prevention program that was not specific to ACL injury prevention 4) Reviews that included non-training interventions such as education or an external device, that is, bracing 5) Reviews that did not report ACL injury data. Meta-analyses that only focused on components of training programs (i.e., specific exercises or dosage), compliance, or only one sport were excluded.		
Evidence for Specific Subgroups of Athletes						
Krutsch 2020	Cohort Study	2	1) Elite men football player on a participating team 2) Played in at least one official match during the season	1) Incomplete questionnaire 2) No playing time during the investigated season 3) Injuries prior to the start of the season.	8 studies; 26 teams; n=529 Intervention 36 teams; n=601 Control Men, mean age 22.2+- 4.3 (intervention) 21.9 +- 4.1 (control), Mean height	**Primary**: Severe knee injury incidence **Secondary:** ACL or PCL, MCL or LCL, cartilage or meniscus, fracture, patella dislocation, thigh injuries, ankle injuries

					1.8+- 4.4m, mean weight 76.3 +- 7.5kg	
Petushek 2019	Meta-analysis	1	1) A prospective controlled trial study design 2) An NMT intervention aimed to reduce incidence of ACL injury 3) Included a comparison group 4)Recorded ACL injury incidence 5) Women	1) No Abstracts, posters, review papers, and irrelevant studies	18 studies; N=27231; Young women athletes	**Primary:** ACL injury odds ratio **Secondary:** Heterogeneity and publication bias

Silvers-Granelli 2017	Randomized Control Study	1	1) Men college soccer player between the ages of 18 and 25 years in good academic standing and was medically cleared to participate in the 2012 season. 2) Teams confirmed that they had not	1) Not meeting inclusion criteria 2) Refused to participate	27 teams; N= 675 in intervention group 34 teams; N = 850 in control group Men college soccer player	**Primary:** Reduction in overall number of ACL injuries **Secondary:** Reduction in rate of ACL injuries based on 1) game v practice setting;

			participated in an injury prevention program in the past 4 academic years .		between the ages of 18 and 25 years	2) player position; 3) level of play; 4) field type
Evidence for components, dosage, and delivery of exercise-based knee injury prevention programs						
Murray 2017	Retrospective Cohort Study	3	Athletic directors in MN high schools that participated in high school boys football and soccer, girls volleyball and soccer	None reported	611 Teams: N= 12,799 football (men) n = 7672 volleyball (women) n =3111 soccer (women) and 3753 soccer (men) All athletes in high school competing for their school team	**Primary:** Number of ACL injuries during sports season **Secondary:** Number of programs that performed IPP with a licensed athletic trainer

Omi 2018	Cohort Study	2	Must play for a women's Japanese collegiate basketball team	None stated.	N=757; n=309 during observation period n=448 during intervention period Women collegiate basketball players. Age 19.6 +/- 1.1 years.	**Primary**: Incidence rate of all ACL injuries and non-contact ACL injuries (observation vs intervention periods I + II) **Secondary:** Incidence rate of all ACL injuries and non-contact ACL injuries in observation vs intervention periods I and observation vs intervention period II relative risk, absolute risk reduction, numbers needed to treat

Objective

Review the evidence in the scientific literature for exercise-based knee injury prevention programs. Evidence includes systematic reviews and meta-analyses that look at prevention programs across populations (**TABLE 2**).

2018 Recommendation

[A] Clinicians should recommend use of exercise-based knee injury prevention programs in athletes for the prevention of knee and ACL injuries. Programs for reducing all knee injuries include 11+ and FIFA 11, HarmoKnee, and Knäkontroll; and those used by Emery and Meeuwisse,[7] Goodall et al,[9] Junge et al,[16] LaBella et al,[18] Malliou et al,[20] Olsen et al,[24] Pasanen et al,[26] Petersen et al,[27] and Wedderkopp et al.[33] Programs for reducing ACL injuries include HarmoKnee, Knäkontroll, Prevent Injury and Enhance Performance (PEP), and Sportsmetrics™; and those used by Caraffa et al,[6] Heidt et al,[11] LaBella et al,[18] Myklebust et al,[22] Olsen et al,[24] and Petersen et al.[27]

Evidence Update

[Level 1] A meta-analysis of meta-analyses was performed by Webster et al [32], and 8 meta-analyses examining efficacy of ACL injury prevention programs were included. All meta-analyses indicated injury prevention programs significantly reduced the risk of ACL injury. There was a 67% reduction in risk for non-contact ACL injuries among women athletes. The findings of this meta-analysis were also supported in a systematic review by Olivares-Jabalera. [23]

[Level 1] A systematic review with meta-analysis was performed to determine how protective ACL injury prevention programs are and what the important components of a prevention program are when accounting for study quality (randomized and cluster-randomized controls as well as studies that included incidence rate).[13] Eight studies with a total of 13,562 participants were included and demonstrated a significant, 53% reduction in ACL injury rates in those participating in an injury prevention program. The specific components for injury prevention programs were not identified, but all but 2 studies provided feedback on exercises and included at least 3 types of exercise.

[Level 1] Two papers reported on men and women in the same RCT examining secondary ACL injury prevention. Johnson et al[14] found no significant difference in rate or side of second ACL injury ($P = .77$ and $P = .25$, respectively) between control and intervention group in women athletes. Additionally, no statistically significant difference was found in rate of second ACL injury based on age category (22.8%

for < 25yo, 28.1% for < 20yo, and 30.8% for < 18yo). Although there was no difference based on type of intervention, the overall second injury rate, particularly the contralateral second injury rate was lower than the published literature.

Arundale et al[3] found 95% of men athletes who participated in ACL-SPORTS trial passed RTS criteria after 1 year, with 78% of athletes returning to preinjury level of play. After 2 years, 100% passed RTS criteria and 95% returned to preinjury level. Overall 2nd ACL injury rate was 0.025 injuries/athlete, also lower than the published literature.

Note: Studies regarding secondary ACL injury prevention were screened for both the 2018 CPG and 2022 update, however none met inclusion/exclusion criteria. In particular, this was due to programs not being specifically targeted at second knee/ACL injuries, or the outcome measure of the study not being knee/ACL injuries.

Evidence Synthesis

2022: The evidence published since 2018 provides further support of the previous recommendation on the use of exercise-based knee and ACL injury prevention. In systematic reviews, meta-analyses, and meta-analyses of meta-analyses there seems to be strong evidence for the benefits of exercise-based knee injury prevention programs, including reduction in risk for all knee injuries and for ACL injuries specifically, with little risk of adverse events and minimal cost.

Two studies from the same RCT provided also new evidence potentially suggesting exercise-based knee injury prevention could beneficial in secondary ACL injury prevention.

Gaps in Knowledge:

Gaps in the literature still exist. The majority of the exercise-based knee and ACL injury prevention programs included in this CPG are designed to be performed as a dynamic warm-up prior to training sessions/practices or games. Recently, programs not specifically focused on knee and ACL prevention, have explored alternative implementation models, such as executing strengthening portions at the end of training sessions/practices [34][Whalan 2019]. Given the success of these programs with alternative structures, both in efficacy and implementation, further research on alternative implementation models within knee and ACL prevention could be valuable. Further, the majority of exercise-based knee and ACL injury prevention studies come from the US, Northern Europe, and Australia, indicating a need for investigations from a wider geographic base.

Further research regarding secondary prevention using exercise-based programs is needed.

2022 Recommendations

[A] Clinicians should recommend use of exercise-based knee injury prevention programs in athletes for the prevention of knee and ACL injuries. Programs for reducing all knee injuries include 11+ and FIFA 11, HarmoKnee, and Knäkontroll; and those used by Emery and Meeuwisse,[7] Goodall et al,[9] Junge et al,[16] LaBella et al,[18] Malliou et al,[20] Olsen et al,[24] Pasanen et al,[26] Petersen et al,[27] and Wedderkopp et al.[33] Programs for reducing ACL injuries include HarmoKnee, Knäkontroll, Prevent Injury and Enhance Performance (PEP), and Sportsmetrics™; and those used by Caraffa et al,[6] Heidt et al,[11] LaBella et al,[18] Myklebust et al,[22] Olsen et al,[24] and Petersen et al.[27]

[C] Clinicians may recommend the use of an exercise-based neuromuscular training program in the late phase of ACL reconstruction rehabilitation for the secondary prevention of ACL injuries

Objective

Identify exercise-based knee injury prevention programs that are effective for specific subgroups of athletes. Evidence includes systematic reviews, meta-analyses, and cohort studies that specifically delineate populations (Table 2).

2018 Recommendations

[A] Clinicians, coaches, parents, and athletes should implement exercise-based knee injury prevention programs prior to athletic training sessions/practices or games in women athletes to reduce the risk of ACL injuries, especially in athletes younger than 18 years of age. Programs that should be implemented include PEP, Sportsmetrics™, Knäkontroll, HarmoKnee, and those used by Olsen et al[24] and Petersen et al.[27]
[A] Soccer players, especially women, should use exercise-based knee injury prevention programs to reduce the risk of severe knee and ACL injuries. Programs that could be beneficial for preventing severe knee injuries include PEP, Knäkontroll, and HarmoKnee. Programs that could be beneficial for specifically preventing ACL injuries include the 11+, SportsmetricsTM and the program used by Caraffa et al[6].
[B] Men and women team handball players, particularly those 15 to 17 years of age, should implement exercise-based knee injury prevention programs. Programs that could be beneficial for preventing knee injuries include those used by Olsen et al[24] and Achenbach et al.[2]

Evidence Update

Men

No new information

Women

[Level 1] In a meta-analysis of studies looking at interventions aiming to reduce incidence of ACL injuries in women athletes, Petushek et al[28] found injury prevention programs that included neuromuscular training reduced ACL injury risk from 1 in 54 to 1 in 111 (odds ratio (OR), 0.51: 95% CI, 0.37, 0.69). Reduction in injury risk was greater for middle school and high school aged athletes (OR, 0.38; 95% CI, 0.24, 0.60) than for college and professional athletes (OR, 0.65; 95% CI, 0.48, 0.89).

Soccer

[Level 2]
Silvers-Granelli et al[30] found decreased rate of ACL injury in men Division I and II soccer players who participated in FIFA 11+ versus the control group (relative risk = 0.24; 95% CI: 0.07, 0.81). No difference found in control versus intervention group in terms of injury rate based on game versus practice, player position, field type, or between Division 1 players. However, a reduction in ACL injury rate was found between intervention group and control in Division II players (relative risk = 0.12; 95% CI, 0.02, 0.93).
[Level 2]

Krutsch et al.[17] aimed to quantify the incidence of severe knee injuries in elite football (soccer) over 1 season by comparing the injury incidence between the implementation of training modules and standard training programs for the prevention of knee injuries. In a large scale cohort study of 26 teams (n=529) in the intervention group and 36 teams (n=601) in the control group, they reported a significant reduction in severe knee injury in the intervention group (0.38 per 1000 hours football exposures; prevalence 9.8%) as compared to the control group (0.68 per 1000 hours football exposures; prevalence 18.0%) ($p < 0.05$).

Team Handball

No new information

Basketball

No new information

Volleyball

No new information

Evidence Synthesis

The evidence published since 2018 around the use of exercise-based prevention programs in soccer players continues to demonstrate efficacy in reducing the risk of knee and ACL injuries. The new evidence bolsters support for the 2018 recommendations, with little risk of adverse events and minimal cost.

Gaps in Knowledge:

Research in sports outside soccer is needed. There was no new research in basketball or volleyball, an high risk team sports such as Netball, Australian Rules Football, as well as individual sports such as skiing, should be both targets of funding organizations and researchers.

2022 Recommendations

[A] Clinicians, coaches, parents, and athletes should implement exercise-based knee injury prevention programs prior to practices/training sessions or games in women athletes to reduce the risk of ACL injuries, especially in athletes younger than 18 years of age. Programs that should be implemented include PEP, Sportsmetrics™, Knäkontroll, HarmoKnee, and those used by Olsen et al[24] and Petersen et al.[27]

[A] Soccer players, both women and men, should use exercise-based knee injury prevention programs to reduce the risk of severe knee and ACL injuries. Programs that could be beneficial for preventing severe knee injuries include PEP, Knäkontroll, and HarmoKnee. Programs that could be beneficial for specifically preventing ACL injuries include the 11+, Sportsmetrics™ and the program used by Caraffa et al[6].

[B] Men and women team handball players, particularly those 15 to 17 years of age, should implement exercise-based knee injury prevention programs. Programs that could be beneficial for preventing knee injuries include those used by Olsen et al[24] and Achenbach et al.[2]

Objective

Describe the evidence for components, dosage, and delivery of exercise-based knee injury prevention programs.

2018 Recommendations

[A] Exercise-based knee injury prevention programs used for women should incorporate multiple components, proximal control exercises, and a combination of strength and plyometric exercises.

[A] Exercise-based knee injury prevention programs should involve training multiple times per week, training sessions that last longer than 20 minutes, and training volumes that are longer than 30 minutes per week.

[A] Clinicians, coaches, parents, and athletes should start exercise-based knee injury prevention programs in the preseason and continue performing the program throughout the regular season.

[A] Clinicians, coaches, parents, and athletes must ensure high compliance with exercise-based knee injury prevention programs, particularly in women athletes.

[B] Exercise-based knee injury prevention programs may not need to incorporate balance exercises, and balance should not be the sole component of a program.

Evidence Update

Components

[Level 2]
A prospective, interventional study demonstrated that participation in hip-focused neuromuscular training reduced non-contact ACL injuries in collegiate women's basketball.[25] Participants received 3 educational sessions on ACL injury-related biomechanics and then completed the intervention program 3 times a week (average of 20min sessions) and exercises were progressed 3 times throughout the season. Exercises included hip strengthening exercises, balance exercises, and basketball-specific jump-landing exercises. The relative risk for non-contact ACL injury in the intervention period versus the observation period was 0.37 and the number needed to treat for non-contact ACL injury was 41.3. Compliance rate throughout the intervention period was 89%. The authors concluded that the reduction in ACL injuries was secondary to a program with multiple components, a focus on the hip, and compliance to the intervention.

Dosage and Delivery

No new information

Compliance

No new information

Evidence Synthesis

There was very little new research in the area of components, dosage and delivery, as well as compliance that met the inclusion criteria of this CPG published since the 2018. Only one study, supporting the use of proximal control/hip strengthening components within exercise-based knee and ACL injury prevention programs was added. Therefore, the evidence continues to support the previous recommendations showing benefits of exercise-based knee injury prevention programs, including reduction of risk for knee and/or ACL injuries, with little risk of adverse events and minimal cost.

Gaps in Knowledge:

More research is still needed on the dose-response relationship of exercise-based knee and ACL injury prevention programs, as well as around improving compliance and adherence.

2022 Recommendations

[A] Exercise-based knee injury prevention programs used for women should incorporate multiple components, proximal control exercises, and a combination of strength and plyometric exercises.

[A] Exercise-based knee injury prevention programs should involve training multiple times per week, training sessions that last longer than 20 minutes, and training volumes that are longer than 30 minutes per week.

[A] Clinicians, coaches, parents, and athletes should start exercise-based knee injury prevention programs in the preseason and continue performing the program throughout the regular season.

[A] Clinicians, coaches, parents, and athletes must ensure high compliance with exercise-based knee injury prevention programs, particularly in female athletes.

[B] Exercise-based knee injury prevention programs may not need to incorporate balance exercises, and balance should not be the sole component of a program.

Objective

Provide suggestions for implementation of exercise-based knee injury prevention programs.

2018 Recommendations

[A] Clinicians, coaches, parents, and athletes should implement exercise-based knee injury prevention programs in all young athletes, not just those athletes identified through screening as being at high risk for ACL injury, to optimize the numbers needed to treat while reducing costs.

[A] For the greatest reduction in future medical costs and prevention of ACL injuries, osteoarthritis, and total knee replacements, clinicians, coaches, parents, and athletes should encourage implementation of

exercise-based ACL injury prevention programs in athletes 12 to 25 years of age and involved in sports with a high risk of ACL injury.
[A] Clinicians, coaches, parents, and athletes should support implementation of exercise-based knee injury prevention programs led by either coaches or a group of coaches and medical professionals.

Evidence Update

[Level 3] A retrospective survey-based study examined availability of neuromuscular training programs in high schools,[21] and whether availability of these programs impacted ACL injury rates. Over 2/3 of respondents reported their high school athletes participated in neuromuscular training, and men's soccer teams participating in neuromuscular training had a significantly lower ACL injury rate ($p< .005$) compared to the literature when an athletic trainer was available for the team. The authors concluded that athletic trainers may help facilitate execution of training programs.

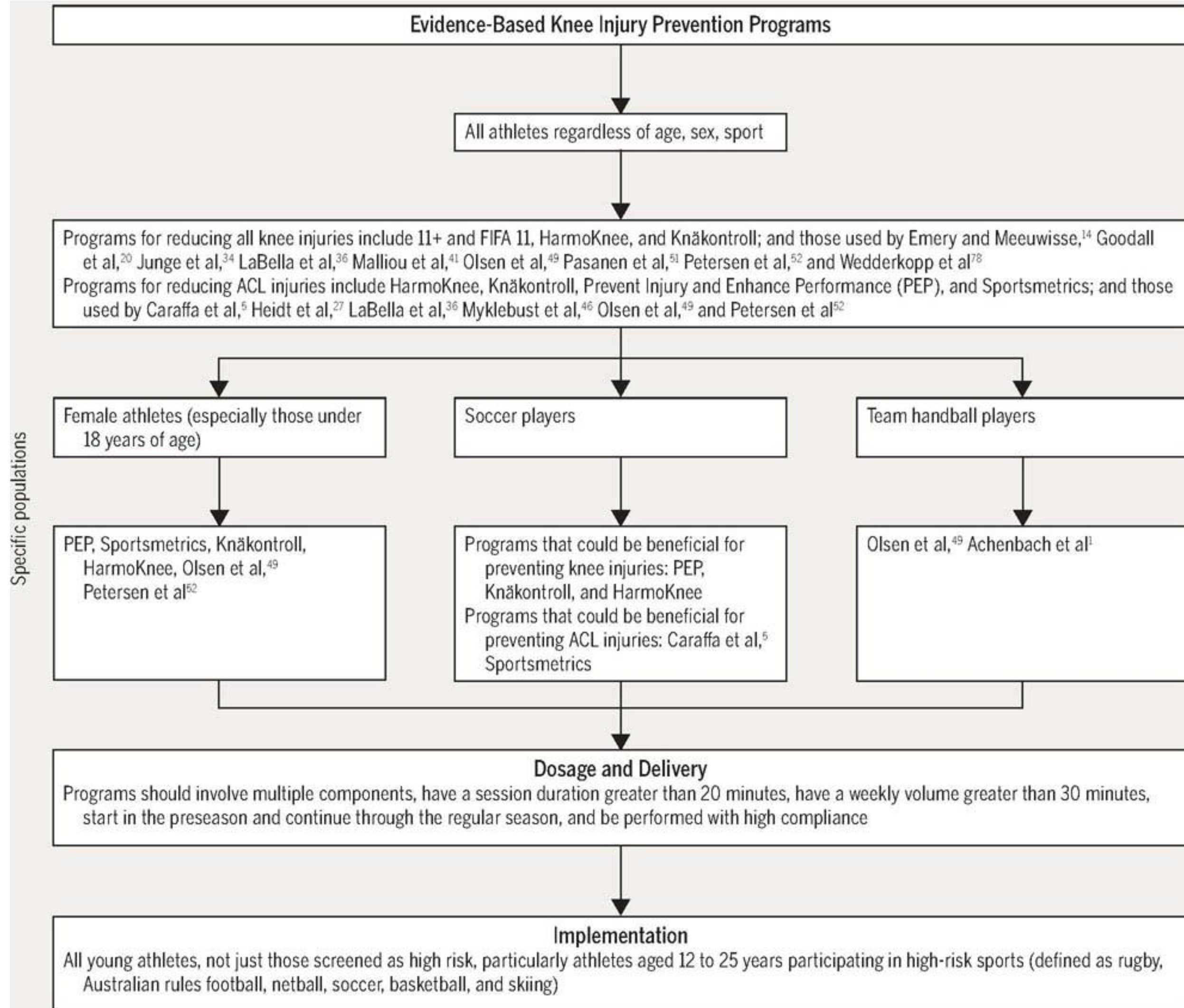
Evidence Synthesis

There was very little new evidence, meeting the inclusion criteria of this CPG, published since 2018 on implementation. The evidence continues to support the previous recommendations that there is no increase in risk of adverse events when all athletes perform prevention programs compared to only athletes screened as high risk, and there is no harm in performing prevention programs. Although cost may minimally increase (depending on the program) as more athletes participate, the small increase in program costs is likely outweighed by long-term health care costs and by the reduction in ACL injuries.
Gaps in Knowledge:
Research around how to engage key stakeholders in exercise-based knee and ACL injury prevention implementation is on-going and implementation remains a crucial step to reducing the burden of knee and ACL injuries [4]. More research, particularly larger scale implementation studies (observational and RCTs) are needed to bolster the evidence.

2022 Recommendations

[A] Clinicians, coaches, parents, and athletes should implement exercise-based knee injury prevention programs in all young athletes, not just those athletes identified through screening as being at high risk for ACL injury, to optimize the numbers needed to treat while reducing costs.
[A] For the greatest reduction in future medical costs and prevention of ACL injuries, osteoarthritis, and total knee replacements, clinicians, coaches, parents, and athletes should encourage implementation of exercise-based ACL injury prevention programs in athletes 12 to 25 years of age and involved in sports with a high risk of ACL injury.
[A] Clinicians, coaches, parents, and athletes should support implementation of exercise-based knee injury prevention programs led by either coaches or a group of coaches and medical professionals.
The recommendations made in this guideline are summarized in **FIGURE 1** .Supplementary videos, originally published in 2018 and located at https://www.jospt.org/doi/suppl/10.2519/jospt.2018.0303 also remain a clinical reference for clinicians based on the findings of both the 2018 and 2022 CPGs.
FIGURE 1.
Treatment algorithm, originally published in 2018 and remaining unchanged in this update, based on CPG findings. The exercise-based knee injury prevention programs heading summarizes the programs observed to be effective when studied across populations. Below the exercise-based knee injury prevention programs heading are the specific populations. These 2 groups (exercise-based knee injury prevention and specific populations) are not mutually exclusive; all programs found in the specific

populations area are also found in the exercise-based knee injury prevention area. However, the program listed for specific populations may be more effective or may have been studied in detail in that particular group. The dosage and delivery and implementation sections provide a summary of recommendations on how programs should be set up and executed.



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Appendix A

Search Strategy for All Databases Searched

PubMed

Search Strategy	Search Limits
(Sports [MeSH] OR Athletes [MeSH] OR Exercise [MeSH] OR Athletic Injuries [MeSH]) AND ((Knee Injuries [MeSH]) OR ((Wounds and Injuries [MeSH] OR injur* [TW]) AND (ACL [TW] OR Anterior Cruciate Ligament* [TW] OR Anterior Cruciate Ligament [MeSH]))) AND (Risk Reduction Behavior [MeSH] OR Prevent* [TW] OR Predict* [TW])	English only, then Clinical Trial, Clinical Trial Phase I, Clinical Trial Phase II, Clinical Trial Phase III, Clinical Trial Phase IV, Comparative Study, Controlled Clinical Trial, Evaluation Studies, Guideline, Introductory Journal Article, Journal Article, Meta-Analysis, Multicenter Study, Observational Study, Practice Guideline, Pragmatic Clinical Trial, Randomized Control Trial, Systematic Reviews, Twin Study

Scopus

Search Strategy	Search Limits
(TITLE-ABS-KEY (Sport*) OR TITLE-ABS-KEY (Athlet*) OR TITLE-ABS-KEY (Exercise) OR TITLE-ABS-KEY (Athletic Injur*)) AND ((TITLE-ABS-KEY (Knee Injur*)) OR ((TITLE-ABS-KEY(Wound*) OR TITLE-ABS-KEY (Injur*)) AND (TITLE-ABS-KEY (Anterior Cruciate Ligament) OR TITLE-ABS-KEY (ACL)))) AND (TITLE-ABS-KEY (Risk Reduction) OR TITLE-ABS-KEY (Prevent*) OR TITLE-ABS-KEY (Predict*))	English only, limit to Article, Review, and Article in Press

SPORTDiscus

Search Strategy	Search Limits
((TI (Sport*) OR AB (Sport*) OR (DE “Sports”)) OR (TI (Athlet*) OR AB (Athlet*) OR (DE “ATHLETICS”)) OR (TI (Exercise) OR AB (Exercise) OR (DE “EXERCISE”)) OR (TI (Athletic Injur*) OR AB (Athletic Injur*))) AND ((TI (Knee Injur*) OR AB (Knee Injur*)) OR ((((TI (Wound*) OR AB (Wound*)) OR (TI (Injur*) OR AB (Injur*))) OR (DE “WOUNDS & injuries”)) AND ((TI (Anterior Cruciate Ligament) OR AB (Anterior Cruciate Ligament) OR (DE “ANTERIOR cruciate ligament”)) OR (TI (ACL) OR AB (ACL))))) AND ((TI (Risk Reduction) OR AB (Risk Reduction)) OR (TI (Prevent*) OR AB (Prevent*) OR (DE “PREVENTION”)) OR (TI (Predict*) OR AB (Predict*)))	English, English Abstract Only, Peer-Reviewed, Academic Journal

CINAHL

Search Strategy	Search Limits
((TI (Sport*) OR AB (Sport*) OR (MH “Sports+”)) OR (TI (Athlet*) OR AB (Athlet*)) OR (TI (Exercise) OR AB (Exercise) OR (MH “Exercise+”)) OR (TI (Athletic Injur*) OR AB (Athletic Injur*) OR (MH “Athletic Injuries+”))) AND ((TI (Knee Injur*) OR AB (Knee Injur*) OR (MH “Knee Injuries+”)) OR ((TI (Wound*) OR AB (Wound*) OR TI (Injur*) OR AB (Injur*) OR (MH “Wounds and Injuries+”)) AND (TI (Anterior Cruciate Ligament) OR AB (Anterior Cruciate Ligament) OR TI (ACL) OR AB (ACL) OR (MH “Anterior Cruciate Ligament+”)))) AND ((TI (Risk Reduction) OR AB (Risk Reduction)) OR (TI (Prevent*) OR AB (Prevent*)) OR (TI (Predict*) OR AB (Predict*)))	English Language checkbox, Adolescent, Adult, Middle-Aged, Aged 65+. Aged 80+, Clinical Trial, Corrected Article, Journal Article, Practice Guidelines, Research, Systematic Review

Cochrane

Search Strategy	Search Limits
((Sport*) OR (Athlet*) OR (Exercise) OR (Athletic Injur*)) AND (((Knee Injur*)) OR (((Wound*) OR (Injur*)) AND ((Anterior Cruciate Ligament) OR (ACL)))) AND ((Risk Reduction) OR (Prevent*) OR (Predict*))	Cochrane Reviews - ALL, Other Reviews, Trials, Technology Assessments, Economic Evaluations

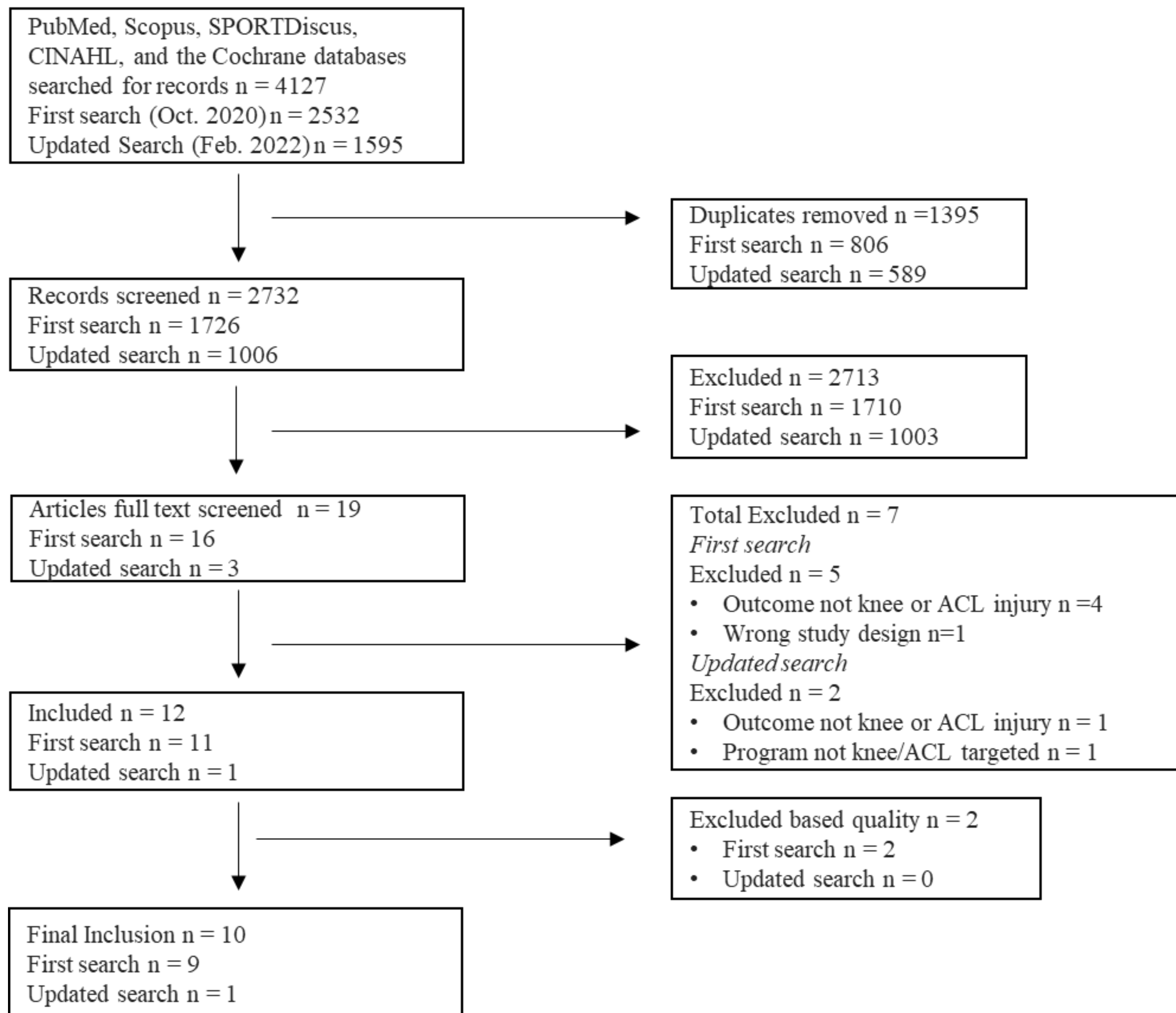
Appendix B

Search Dates and Results

Database	Search 10/23/2020	Search 2/18/2022
PubMed	342	208
Scopus	1297	904
Sports Discus	238	141
CINAHL	227	129
Cochrane Library	328	213
Cochrane reviews	68	36
Cochrane protocols	13	9
Trials	246	167
Clinical answers	1	1
Total	2532	1595
Total with duplicates removed	1742	1221

Appendix C

Flow Chart of Literature Review Process



Appendix D

Included Articles

2022:

Arundale AJH, Capin JJ, Zarzycki R, Snyder-Mackler L, Smith AH. Two Year Acl Reinjury Rate of 2.5%: Outcomes Report of the Men in a Secondary Acl Injury Prevention Program (Acl-Sports). International Journal of Sports Physical Therapy. 2018;13(3):422-31

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Johnson JL, Capin JJ, Arundale AJH, Zarzycki R, Smith AH, Snyder-Mackler L. Secondary Injury Prevention Program May Decrease Contralateral Anterior Cruciate Ligament Injuries in Female Athletes: 2-year Injury Rates in the ACL-SPORTS Randomized Control Trial. The Journal of orthopaedic and sports physical therapy. 2020:1-28.

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2018:

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Donnell-Fink LA, Klara K, Collins JE, et al. Effectiveness of knee injury and anterior cruciate ligament tear prevention programs: a meta-analysis. *PLoS One*. 2015;10:e0144063. https://doi.org/10.1371/journal.pone.0144063

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Appendix E

Quality-Assessment Scores

Systematic Reviews and Meta-analyses: AMSTAR Checklist*

Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Quality**
Huang et al[13]	X	X	X			X	X	X	X	X	X	9
Olivares-Jabalera et al[23]	X		X			X	X				X	5
Petushek et al[28]	X	X	X			X	X	X	X	X	X	9
Webster et al[32]		X		X	X	X		X				5

Abbreviation: AMSTAR, A Measurement Tool to Assess Systematic Reviews.

*

Yes/no. Items: 1, Was an a priori design provided? 2, Was there duplicate study selection and data extraction? 3, Was a comprehensive literature search performed? 4, Was the status of publication (ie, gray literature) used as an inclusion criterion? 5, Was a list of studies (included and excluded) provided? 6, Were the characteristics of the included studies provided? 7, Was the scientific quality of the included studies assessed and documented? 8, Was the scientific quality of the included studies used appropriately in formulating conclusions? 9, Were the methods used to combine the findings of studies

appropriate? 10, Was the likelihood of publication bias assessed? 11, Was the conflict of interest included?

†

What is your overall assessment of the methodological quality of this review? High quality, 8 or greater; acceptable, 5, 6, or 7; reject, 4 or less.

Randomized Controlled Trials: Physiotherapy Evidence Database Scale (PEDro)*

Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Quality**
Arundale et al [3]	X	X	X	X			X	X	X	X	X	9
Johnson et al[15]	X	X	X	X			X	X	X	X	X	9
Silvers-Granelli et al[30]	X	X		X				X	X	X	X	7

*

Items: 1, Eligibility criteria were specified; 2, Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received); 3, Allocation was concealed; 4, The groups were similar at baseline regarding the most important prognostic indicators; 5, There was blinding of all subjects; 6, There was blinding of all therapists who administered the therapy; 7, There was blinding of all assessors who measured at least 1 key outcome; 8, Measures of at least 1 key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9, All subjects for whom outcome measures were available received the treatment or control condition as allocated, or, where this was not the case, data for at least 1 key outcome were analyzed by "intention to treat"; 10, The results of between-group statistical comparisons were reported for at least 1 key outcome; 11, The study provides both point measures and measures of variability for at least 1 key outcome.

†

Quality rating: 8 or higher, high; 5, 6, or 7, acceptable; 4 or less, reject.

Cohort Studies: Scottish Intercollegiate Guidelines Network Checklist (SIGN)*

Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Quality**
Krutsch et al	X	X	X		X		X								5
Murray Et al	X	X			N/A	N/A	X	N/A	X				X	~~X~~	~~6~~

*

Items: 1, The study addresses an appropriate and clearly focused question; 2, The 2 groups being studied are selected from source populations that are comparable in all respects other than the factor under investigation; 3, The study indicates how many of the people asked to take part did so, in each of the groups being studied; 4, The likelihood that some eligible subjects might have the outcome at the time of enrollment is assessed and taken into account in the analysis; 5, What percentage of individuals or clusters recruited into each arm of the study dropped out before the study was completed? 6, Comparison is made between full participants and those lost to follow-up, by exposure status; 7, The outcomes are clearly defined; 8, The assessment of outcome is made blind to exposure status (if the study is retrospective, this may not be applicable); 9, Where blinding was not possible, there is some recognition that knowledge of exposure status could have influenced the assessment of outcome; 10, The method of assessment of exposure is reliable; 11, Evidence from other sources is used to demonstrate that the method of outcome assessment is valid and reliable; 12, Exposure level or prognostic factor is assessed more than once; 13, The main potential confounders are identified and taken into account in the design and analysis; 14, Have confidence intervals been provided?

†

How well was the study done to minimize the risk of bias or confounding? Quality rating: 8 or higher, high; 5, 6, or 7, acceptable; 4 or less, reject.

Appendix F

Levels of Evidence Table*

Level	Intervention/Prevention	Pathoanatomic/Risk/Clinical Course/Prognosis/Differential Diagnosis	Diagnosis/Diagnostic Accuracy	Prevalence of Condition/Disorder	Exam/Outcomes
I	Systematic review of high-quality RCTs High-quality RCT†	Systematic review of prospective cohort studies High-quality prospective cohort study‡	Systematic review of high-quality diagnostic studies High-quality diagnostic study§ with validation	Systematic review, high-quality cross-sectional studies High-quality cross-sectional study‖	Systematic review of prospective cohort studies High-quality prospective cohort study
II	Systematic review of high-quality cohort studies High-quality cohort study‡ Outcomes study or ecological study Lower-quality RCT¶	Systematic review of retrospective cohort study Lower-quality prospective cohort study High-quality retrospective cohort study Consecutive cohort Outcomes study or ecological study	Systematic review of exploratory diagnostic studies or consecutive cohort studies High-quality exploratory diagnostic studies Consecutive retrospective cohort	Systematic review of studies that allows relevant estimate Lower-quality cross-sectional study	Systematic review of lower-quality prospective cohort studies Lower-quality prospective cohort study
III	Systematic reviews of case-control studies High-quality case-control study Lower-quality cohort study	Lower-quality retrospective cohort study High-quality cross-sectional study Case-control study	Lower-quality exploratory diagnostic studies Nonconsecutive retrospective cohort	Local nonrandom study	High-quality cross-sectional study
IV	Case series	Case series	Case-control study	…	Lower-quality cross-

					sectional study
V	Expert opinion	Expert opinion	Expert opinion	Expert opinion	Expert opinion

Abbreviation: RCT, randomized clinical trial.

*

Adapted from Phillips et al[Burton] (http://www.cebm.net/index.aspx?o=1025). See also **APPENDIX G**.

†

High quality includes RCTs with greater than 80% follow-up, blinding, and appropriate randomization procedures.

‡

High-quality cohort study includes greater than 80% follow-up.

§

High-quality diagnostic study includes consistently applied reference standard and blinding.

‖

High-quality prevalence study is a cross-sectional study that uses a local and current random sample or censuses.

¶

Weaker diagnostic criteria and reference standards, improper randomization, no blinding, and less than 80% follow-up may add bias and threats to validity.

Appendix G

Procedures Used for Assigning Levels of Evidence

Level of evidence is assigned based on the study design using the Levels of Evidence table (**APPENDIX F**), assuming high quality (e.g. for intervention, randomized clinical trial starts at level I)
Study quality is assessed using the critical appraisal tool, and the study is assigned 1 of 4 overall quality ratings based on the critical appraisal results
Level of evidence assignment is adjusted based on the overall quality rating:
High quality (high confidence in the estimate/results): study remains at assigned level of evidence (e.g. if the randomized clinical trial is rated high quality, its final assignment is level I). High quality should include:
Randomized clinical trial with greater than 80% follow-up, blinding, and appropriate randomization procedures
Cohort study includes greater than 80% follow-up
Diagnostic study includes consistently applied reference standard and blinding
Prevalence study is a cross-sectional study that uses a local and current random sample or censuses
Acceptable quality (the study does not meet requirements for high quality and weaknesses limit the confidence in the accuracy of the estimate): downgrade 1 level
Based on critical appraisal results
Low quality: the study has significant limitations that substantially limit confidence in the estimate: downgrade 2 levels
Based on critical appraisal results
Unacceptable quality: serious limitations—exclude from consideration in the guideline
Based on critical appraisal results

Footnotes

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