

Consensus Opinion on the Best Practice Features of Lower Limb Injury Prevention Programs (LLIPP)

Lower limb injuries are common injuries in sports (1). Previous injury is a strong risk factor for future osteoarthritis (5). Anterior cruciate ligament (ACL) injury significantly increases a person's risk for osteoarthritis (OA) in the injured knee. OA is a chronic, painful and disabling disease, and can occur as early as 10-15 years after the ACL injury and regardless of treatment. Studies suggest a beneficial effect of ACL injury prevention programs (IPP) on reduction in ACL injuries (13, 17). The number of athletes needed to enroll in an ACL IPP to prevent one ACL tear is approximately 89-108 (5, 17). This makes ACL IPP more cost-effective than surgical treatment of ACL injury (8, 18).

The Osteoarthritis (OA) Action Alliance is a national coalition of concerned organizations mobilized by the Arthritis Foundation and the Centers for Disease Control and Prevention (CDC). Our injury prevention working group comprises injury prevention experts from many different national organizations. We performed a literature search of multiple systematic reviews and meta-analyses have attempted to identify the essential components required for an effective ACL IPP (2, 3, 7, 9, 12, 16, 19, 20). Based on comprehensive review of this literature, our working group recommends that the following six core components (with several examples of exercises) be included in a structured warm-up to maximize effectiveness of lower extremity IPPs for youth athletes:

- (1) **Lower extremity and core muscle strength training** (2, 3, 5, 7, 9, 15, 16, 20) Examples of appropriate exercises include but are not limited to: Nordic hamstring exercises, planks (different variations), squats with proper technique, lunges (different planes of movement)
- (2) **Plyometrics – Jump Training** (2, 3, 5, 9, 20) Examples of appropriate exercises include but are not limited to squat jumps, side-to-side jumps, tuck jumps, single leg jumps, travelling jumps, 180 degree jumps.
- (3) **Balance exercises as a component** (2, 3, 7, 9, 11), **but not the sole component** of the ACL IPP program (19).
- (4) **Continual feedback to athletes regarding proper technique**, including reminders to bend at knees and hips, to land softly, to keep knees over toes, and to avoid dynamic knee valgus (i.e., knees caving inward) (2, 7, 9, 12)
- (5) **Sufficient dosing**: For optimal results from a LLIPP, a minimum of 6 weeks (about 2-3 fifteen minute sessions per week) is suggested as pre-season conditioning after which time the program should be used as a warm-up before practices and games for in-season maintenance (2, 14). Higher athlete compliance results in fewer ACL injuries, fewer acute knee and lower extremity injuries. (2, 4, 6, 8, 10, 14)
- (6) **Minimal-to-no additional equipment** (7) is required. A mat for some of the exercises is desirable but not necessary.

Optional Components:

- (7) **Stretching:** There is not enough evidence to support static stretching in ACL injury prevention. Dynamic stretching may be beneficial for other reasons, including perceptions about flexibility exercises being a critical aspect of warm-up activities, but additional research is needed to understand how stretching influences risk for ACL injury (2, 7, 19).
- (8) **Agility exercises:** There is not enough evidence to support agility exercises in ACL injury prevention; although, the addition of this component creates an opportunity to add sport-specific training. Instruction and feedback is required during faster movements (e.g., Side shuffle exercises, carioca, cutting, etc.)

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