Jumping Sports

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Gian Luigi Canata, Luca Pulici, Gaspare Pavei, and Valentina Casale

77.1 Characteristics of the Sport

The main disciplines of track and field jumping activities are high jump, long jump, triple jump, pole vault, and hurdling. Still, vertical jumping ability is a very important skill in several sports, such as football, basketball, volleyball, gymnastics, figure skating, dancing, martial arts, rugby, and much more. The ultimate goal of a jumping activity is to reach the longest distance, which could be vertical or horizontal. Standing long jump was a discipline practiced in the ancient Olympic Games, where athletes used also handheld weights (halteres) to increase the body center of mass trajectory and then jump distance. Nowadays, there are two horizontal jumps at Olympics, long and triple jump, and two vertical, high jump and pole vault, where an external aid, a pole, is used to clear the greatest height.

G. L. Canata (✉) · V. Casale
Centre of Sports Traumatology, Koelliker Hospital, Turin, Italy

L. Pulici
FC Internazionale Milano, Milan, Italy

Knee Surgery and Sports Traumatology Unit, Humanitas Research Hospital, Rozzano, Milan, Italy

G. Pavei
Laboratory of Physiomechanics of Locomotion, Department of Pathophysiology and Transplantation, University of Milan, Milan, Italy

77.2 Physiological and Biomechanical Demands on Athletes

In all the jumping activities the final distance undergoes the physics law of "projectile motion," according to which in horizontal jumps the main determinants of the final performance are the takeoff speed and takeoff angle.

In order to achieve the highest manageable speed, athletes complete a running approach prior to takeoff that must be performed before a board.

1. The last two steps are peculiar in the long jump: they differ in length, as the penultimate is longer than the last one, and the body is usually lowered in order to gain an upward impulse at takeoff (this general description is tailored on athlete's characteristics and can vary in different techniques).
2. Since takeoff speed should be the highest possible, it is important that during these last steps, the top speed reached during the running approach is maintained. At takeoff, the foot should be placed flat in order to maintain balance and produce a great vertical impulse: for this reason, contact time at takeoff is longer than during run-up and the foot is placed ahead the body center of mass to increase the time for force generation, without excessively decreasing horizontal speed. Takeoff angle is

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less than the 45° that is commonly presented for projectile motion, firstly because takeoff height and landing are not the same, and secondly because horizontal speed is higher than vertical speed; so that top athletes jumps with an angle range of 20–30°.
3. In the flight phase, three main techniques have been selected by athletes to counteract the rotation due to takeoff: sail, where legs are lifted to reach the landing position; hang, where both arms and legs are extended and reach the greatest distance from the hip; hitch-kick, a dynamic configuration in which athletes perform one or more steps as if "running on air."
4. The landing is also important, because jump length is measured from the first indentation in the sand to the takeoff board. As for the different landing techniques, their ultimate purpose is to hit the ground as far as possible and to allow athletes going away from the landing site without falling back.

When the goal is to clear a bar at the greatest possible height, the vertical displacement must be maximized. The Fosbury-flop high jump technique is composed by three phases: the J-shaped approach run, the takeoff and the flight and bar clearance.

1. In the first phase the athlete gains speed during the straight part of the approach, then during the curvilinear part the athlete leans his body to the center of the circle and prepares for takeoff.
2. Takeoff begins with the athlete body in a straight line with a backward and inward lean, with flat foot. At takeoff, the horizontal speed has to be redirected to vertical speed by the pushing leg, which is internal in the curvature. During the takeoff support phase, hip and knee should flex the least possible and maintain the body in a straight line to enhance stiffness. The push is completed with the full extension of knee and hip and great power generation from the ankle. The swinging leg is elevated with bent knee.
3. During flight, the swinging leg rotates medially to the body so that the athlete back faces the bar. Clearance of the bar is performed by arching the body over the bar and the jump ends by landing on the mat.

Triple jump consists in a sequence of three jumps: hop, step, jump. Whereas hop and step are performed on the runway, in the jump the athlete lands on sand.

1. The triple jump length is measured from the board to the sand. The running approach is always aimed to reach the highest speed, but it is very important for the athlete to control this speed at takeoff, since in the triple jump there are three subsequent takeoffs and their correct execution is mutually related.
2. Hop landing must be performed on the same foot of takeoff, step landing on the contralateral, whereas jump landing is, as for long jump, on both feet. Using both feet (one at a time) for takeoff and landing differs from all the other jumps and the athlete needs to be well balanced between his right and left side.
3. Hop, step, and jump length are not the same and both the athlete's ability and the different techniques adopted may determine a "hop-dominated," a "jump-dominated," or a "balance jump" when the phase differs for more than 2% from the others. Arm action is still much debated, and athletes can use the single or the double arm technique; the different techniques are supposed to counteract trunk torsions, to enhance lower limb momentum, to maintain horizontal speed, and to cushion stance leg during impact.
4. In the triple jump, as well as in every discipline consisting in multiple phases, each movement is affected by the preceding phases: this explains why the ability of the coordinative units to adapt to perturbations is important.
5. During each takeoff moment, a change in the movement structure and rhythm occurs, impacting the timing of each concentric and eccentric contraction. As a result, each takeoff phase presents a specific dynamic requirement during the breaking and propulsive moments. The contact between the foot and the ground

causes a decrease of the vertical and horizontal velocity of the jumper. To perform the longest possible jump, the loss in horizontal velocity during the support phases may be minimized while gaining vertical velocity.
6. In the triple jump, as in all the jumping activities characterized by multiple phases, the horizontal-to-vertical velocity conversion is a fundamental skill for a successful jumping performance.

In order to jump higher than 2.45 m (the actual high jump world record), athletes need to use external aids. Pole vault is the only discipline that allows an external aid, a pole, to help athlete in performing the greatest height.

1. Classically, the pole vault is divided into seven distinct stages: run-up, transition with arm elevation in the last three steps, takeoff including the pole plant, swing phase, rock-back, inversion position, and bar clearance.
2. As for all other jumps, pole vault starts with a linear running approach with the athlete running with the pole kept with both his hands. This approach is essential to gain the highest manageable speed. On the penultimate step the hands are raised and pushed forward the pole, and the pole is planted.
3. At the takeoff the pole is against the "stop board" of the box, the athlete's arms are straight pushed forward to the pole, takeoff leg is fully extended and pushed to the pole, while swing leg is bent at knee and elevated. In this instant and in this position, the athlete aims to convert all the kinetic energy gained during the approach into the elastic pole that starts bending: this deformation is energy storage.
4. After bending, the pole comes back to the straight position and the athlete goes upward with the extending pole, attached to it. When the pole is back in the vertical straight position, the athlete pushes off from the pole with one hand, rotates the body so that torso faces the bar and clears the bar by arching the body; when the bar is cleared, he lands on the mat with his back.

In all these jumping activities, the lower limbs are highly stressed, because they must absorb and generate forces and power in the three planes of motion up to 10 times the body weight. During high jump, the ankle and the knee transfer forces and power even though they are not on the same axis. In triple jump, balance is very important among stance phases and in pole vault torso and arm muscles give and counteract the forces to the pole at takeoff. Muscles work in all the three possible ways: by shortening (concentric), by lengthening (eccentric), and isometrically. Moreover, they act synergically with tendons to exploit more power, for example, via stretch-shortening-cycle, elastic energy, and power amplification. From a metabolic point of view, all this power can be produced only by the anaerobic alactic mechanism: fuel stores of adenosine triphosphate (ATP) and phosphocreatine (PC) may provide immediate high power through the breakdown of these stored high-energy phosphates.

77.3 Epidemiology of Injuries

Jumping and landing, which frequently occur during sports events, may be soft or rigid, depending on the biomechanical energy loss. Particularly interesting are the stop-jump maneuvers, typically performed in several sports disciplines and often responsible of sports injuries. Among the field events in athletics, horizontal jumps (long and triple jump) and vertical jumps (high jump and pole vault) involve the production of maximum force in a short period of time; the resulting maximal muscle contractions cause high stress on several body districts, and this is the most common type of lesions related to jumping sports. The great majority of injuries are reported in the lower extremities, in particular the thigh region. Furthermore, also the knee, the ankle, and the hip joints are frequently involved in jumping traumatic events. Patellar tendinopathy, also called the jumper's knee, typically affects athletes involved in repetitive jumps. The low back pain is a widespread problem in athletes and commonly occurs when performing continuous flexion, hyperextension, and rotation movements

along the vertebral segments, such as during high jump and pole vault. It may have a discogenic, articular, or muscular origin or may be secondary to ligamentous and/or vascular pathologies.

Stress injuries may be included among the sports-related affections. In particular, it has been observed that high jumpers, especially female amenorrheic athletes, typically report the medial malleolus of the tibia and tarsal navicular stress fracture. Overuse injuries result from a mismatch between the resilience of the connective and supporting tissue and sports activity. The detection of the genetic background related to susceptibility to sports injuries is challenging. The incidence of overuse injury has decreased over the years, maybe due to improved recovery methods or training strategies; nevertheless, it has also been reported that they tend to be underreported.

77.4 Specific Rehabilitation and Return to Play

The classical conservative treatment consists in rest and soft tissue manipulation techniques, with the addition of manual stretching and other therapies such as diathermy, laser therapy, and shock waves. Programs are adjusted according to the site and the degree of injury, as well as to the individual characteristics and demands of the athlete.

Cryotherapy is the most common treatment for the acute management of musculoskeletal injuries. It reduces the metabolic rate of tissues and prevents surrounding tissues from possible enzymatic reactions after injuries and inflammatory responses. It is possible to choose between the cold-water immersion (CWI), local cryotherapy, a whole-body cryotherapy (WBC), and partial-body cryotherapy (PBC). The use of WBC or PBC in sports aims to limit the spread of muscle lesion after training or competing; it may also be a prophylactic option to reduce the risk of muscle lesion in case of intense training sessions and to improve the antioxidant status after multiple exposures. Nevertheless, the benefits of the cryotherapy are still debated in the literature, probably due to the several different methodologies used, such as the temperature and the treatment duration.

Trunk stabilization exercises are generally proposed to train a synergic action of the deep abdominal muscles, with special regard to the internal and transverse obliques of the abdomen, as well as the adductors and extensors of the lumbar tract.

The **training program** is generally divided into three phases: the first one works on synchronized isometric contractions of the different muscle groups at the level of the pelvis; the second one focuses on core stability with unstable surfaces in addition to aerobic training; the third phase includes specific sports exercises with gradual return to the competitive activity.

Ankle injuries are relatively rare among the jumping athletics disciplines; however, unexpected changes of direction may cause ligamentous lesions and a possible development of an anterior ankle instability.

From a rehabilitative point of view, a gradual recovery of the correct **ROM** in all directions of movement may be recommended, as well as stretching, with particular attention to the plantar flexors. As second stage, a progressive reinforcement of the ankle muscles is suggested, especially the peroneus and the tibialis anterior. The program starts from an isometric reinforcement rather than an isotonic one, followed by a proprioceptive training, with particular emphasis to the single standing leg exercise in a multitasking way. This scheme usually leads the athlete to a gradual return to competitive activity.

The **treatment** of the jumper's knee involves an initial phase aimed to reduce pain with isometric exercises and a management of daily life activities according to the pain threshold; then, thigh muscles reinforcement and lengthening is recommended, followed by a gradual return to the agonistic activity. There is no evidence on the efficacy of bracing and kinesiotaping, especially in the long term; on the contrary, the best treatment for this pathology seems to be an exercise—based program and the improvement of jumping technique. Other types of passive therapies, such as the deep transversal massage to be performed on the tendon and the fascial manipulation on the

thigh extensor compartment, also seem to have effect only in the initial reduction of the symptomatology. The stop period and the adequate time of return to play are highly variable; in the best of cases the athlete can resume full-load training after 20 days, in the most complex and chronic cases even after 6 months. The literature suggests the McKenzie method as the best treatment option for the low back pain, despite the high rate of recurrence; in fact, 20% of the athletes report again the same symptomatology after only 6 months. Further treatment options proposed in the literature are manipulative techniques, flexion and extension exercises, lumbar spine strengthening exercises.

77.5 Specific Aspects in Different Subpopulations

- It has been reported that different ethnicities show different responses to strenuous exercise, when considering immune and inflammatory reactions and the relative serum cytokine levels augmentation. In particular, the increase is higher in African runners than Caucasians from 6 h postexercise, suggesting that ethnicity may affect the entity of an exercise-induced muscle damage.
- The female sex shows a higher risk of jumping-related injuries, especially when considering stress fractures, mostly affecting female amenorrheic athletes as cited above, and non-contact anterior cruciate ligament injury affecting young, adolescent female athletes.
- When considering the higher rate of non-contact ACL injury, it has been demonstrated that, during high-risk situations, female athletes show muscle activation patterns causing a higher risk of ACL injury: some examples are a higher quadriceps muscle activation, which increases the magnitude of anterior tibial shear forces with a consequent ACL strain, and reduced hamstring muscle activation during the high-risk movement conditions (such as side cutting and stop landing), which provides less protective capacity for ACL unloading.
- When considering stress fractures, the reasons of the higher incidence among young female athletes than males are still under debate. Certainly, the "female athlete triad" (menstrual irregularity, eating disorders and osteoporosis) increases the susceptibility to these injuries.

77.6 Prevention Strategies

Injuries may be influenced by intrinsic and extrinsic risk factors. Identification and management of these elements is crucial to prevent further lesions. Intrinsic risk factors consist in previous injuries, anatomic or biomechanical affections (such as a *genu valgum*), strength or flexibility imbalances, and physiologic deficits. In case of abnormal gait biomechanics, such as increased pronation excursion and dorsiflexion, the use of foot orthoses may reduce the injury rate. Extrinsic risk factors include training errors related to duration (too much), intensity (too fast), and frequency (too soon), as well as workout characteristics and improper techniques. This last concept is fundamental for jumping injuries, because only a correct jumping technique may prevent traumas.

The Academy of Nutrition and Dietetics, the Dietitians of Canada, and the American College of Sports Medicine have recently outlined the current energy, nutrient, and fluid recommendations for active adults and competitive athletes; they also emphasized the need to adapt them to health, nutrient needs, performance goals, and physical characteristics of each athlete.

A wide range of themes, including the general recommendations about contemporary sports nutrition, have been identified:

- Nutrition programs should be personalized to the single athlete, according to the sports event, performance goals, food preferences, practical challenges, and to the responses to various strategies.
- The development of metabolic efficiency and flexibility is a fundamental aspect of training; at the same time, competition nutrition strategies

must give substrate stores to meet the fuel demands during the sport event and to support cognitive function.
– Functional and metabolic adaptation of the body results from the interaction between training and nutrition. The stronger and more effective this relationship is, the less necessary proactive nutrition support will be to enhance training adaptations.

77.7 Equipment and Protection Considerations

To date, it is under debate if minimal shoes provide satisfying stability during complex and rapid movements, such as dynamic stabilization following jumping, change of direction, and cutting maneuvers. Several studies have reported that, compared to barefoot situations, the use of footwear causes stiffness of the lower extremities during hopping and jump landing, as well as lower extremity muscle activation amplitudes during jump landing stabilization.

This may be explained by different mechanical strategies for controlling peak impact forces during jumping and jump landing. A recent study has compared the effects on jump landing deriving from standard, minimalist or no footwear. Shoe flexibility and reduced sole support seem to have no, or only minimal influence on static and dynamic postural control, since they do not increase the risk of traumatic events during sports activities. However, barefoot standing showed the greatest postural sway velocity; therefore, barefoot conditions should be considered carefully when an adequate postural control is needed.

77.8 Other Health Aspects and Diseases

Jumping is technically demanding and requires adequate fitness and specific skills: any disease altering neuromuscular efficiency may be dangerous and jumping should be discouraged in these conditions.

77.9 Match Rules with Medical Importance

In case of an impairing injury, competition should be discontinued. Further match rules regarding medical importance are not available.

77.10 Fact Box

– All the jumping activities, particularly in athletics, require a repeated production of maximum force in a short period of time determining a risk of stress injuries.
– Injuries in the lower extremities, specifically the thigh region, the knee, the ankle, and the hip joints, typically occur in the jump events.
– Conservative programs vary according to the site and the degree of injury. They include rest, stretching, and exercise-based programs and/or passive therapies such as soft tissue manipulation techniques, kinesiotaping, cryotherapy, etc.
– Prevention strategies aim at correcting anatomic or biomechanical abnormalities as well as improving training errors or improper techniques.

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