Prevention of Ligament Injuries

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Contents

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Introduction

Sometimes the proper management of sports injuries can be complex and challenging to the sports medicine clinician. It is even more demanding to prevent athletic injuries and programming the rehabilitation after a joint lesion. Structural and neuromuscular mechanisms are disrupted in case of an injury and the continuation of information processing is ceased, which would lead to performance deteriorations and re-injury. From the point of view of sports medicine, the coordination of a movement is mainly the internal organization of the optimal control of the motor system and its parts, thus ligaments play an important role. Coordination has been defined as a cooperative interaction between nervous system and skeletal muscles [33]. This is particularly important for the prevention of injuries in risky situations.

During any voluntary movements or perturbations occurring in gait, running, or jumping, due to rapid responses of lower, and to some extent, upper extremities, musculature of these parts play an important role in keeping desirable posture. Afferent information for necessary fine tuning of motor control is provided by proprioceptive, visual, vestibular, and somatosensorial receptors.

Somatosensorial receptors are located in muscles, tendons, joints, and other tissues. Proprioception relates primarily to the position sense of mechanoreceptive sensation, which includes tactile and position sense. Biomechanically, there is a considerable load on musculotendinous and capsular structures, together with joint contact forces. Trauma to tissues may result in partial deafferentation by causing mechanoreceptor damage, which can lead to proprioceptive deficits. Consequently, susceptibility to re-injury may become a possibility because of this decrease in proprioceptive feedback.

The effect of ligamentous trauma resulting in mechanical instability and proprioceptive deficits contributes to functional instability, which could eventually lead to further microtrauma and reinjury.

M.N. Doral et al. (eds.), *Sports Injuries*,
DOI: 10.1007/978-3-642-15630-4_5, © Springer-Verlag Berlin Heidelberg 2012

Ankle Injuries, Clinical Importance, and Prevention Through Proprioceptive Training

Ankle sprains are defined as the most common musculoskeletal injuries that occur in athletes [1, 2]. Several studies have noted that sports requiring sudden stops and cutting movements like soccer cause the highest percentage of these injuries [3]. Ankle sprains not only result in significant time loss from sports participation, they can also cause long-term disability and have a major impact on health care costs [2]. Functional instability of the ankle is one of the most common residual disabilities after an acute ankle sprain. Ankle joint instability can be defined as either mechanical or functional instability. Mechanical instability refers to objective measurement of ligament laxity, whereas functional instability is defined as recent sprains and/or the feeling of giving way. Casual factors include a proprioceptive deficit, muscular weakness, and/or absent coordination [12]. Ankle instability, as a result of partial deafferentation of articular mechanoreceptors, with joint injury was first postulated by Freeman [15]. They observed that a decrease in the ability to maintain a one-legged stance occurred in the sprained ankle versus the contralateral uninjured ankle. Konradsen and Ravn [22] attributed the cause of functional instability to both mechanical and functional causes in stating that functional instability results from "damage to mechanical receptors in the lateral ligaments or muscle/tendon with subsequent partial deafferentiation of the proprioceptive reflex".

According to the results of studies, the most frequent injuries of adolescent [4, 6] and female [7] soccer players are ankle sprains. Some of the intrinsic risk factors involved in ankle injuries have been identified as previous sprains, foot type and size, ankle instability, joint laxity, reduced lower extremity strength, and anatomic malalignment [5, 8]. Dvorak et al. [11] also supported the observation by Inklaar [18] who stated that the high rate of reinjury suggests that inadequate rehabilitation or incomplete healing is an important risk factor. Soccer, like most sports, is associated with a certain risk of injury for the players. However, scientific studies have shown that the incidence of football injuries can be reduced by prevention programs [26, 31, 36].

Knee Injuries, Clinical Importance, and Prevention Through Proprioception

The presence of neuroreceptors in the human knee joint had been described by Rauber over a 100 years ago, whereas the presence of numerous mechanoreceptors in the human anterior cruciate ligament (ACL) was well documented in the 1980s [5].

Proprioception may play a protective role in acute knee injury through reflex muscular splinting. Kennedy et al. [21] hypothesized that loss of mechanoreceptor feedback from torn knee ligaments contributed to a vicious cycle of loss of reflex muscular splinting, repetitive major and minor injury, and progressive laxity.

The protective reflex arc initiated by mechanoreceptors and muscle spindle receptors occurs much more quickly than the reflex arc initiated by nociceptors (70–100 m/s vs 1 m/s). Thus, proprioception may play a more significant role than pain sensation in preventing injury in the acute setting [23].

In addition to mechanical disruption of articular structures following injury, the loss of proprioception may have a profound effect on neuromuscular control and the activities of daily living. It appears that neurological feedback mechanisms originating in articular and musculotendinous structures provide an important component for the maintenance of functional joint stability [24]. Articular deafferentation results following the injury to capsuloligamentous structures. This contributes to alterations in kinesthesia and joint position sense and further degenerative changes in the joint, as the spinal reflex pathway may be impaired [24].

Effect of Fatigue on Reflex Inhibition

Endurance training is known to result in neuromuscular adaptations that would alter the production and/or clearance of metabolic substrates. Soccer is considered as an endurance event, mainly. It can be speculated that fatigue may well result in lower muscular response to inversion. Walton et al. [38] have studied to determine the extent of reflex inhibition during and after fatigue in endurance-trained individuals compared to sedentary controls. Subjects have been found to produce isometric ankle plantar-flexion contractions at 30% of maximal voluntary contraction (MVC) until their MVC torque declined by 30%. H-reflexes have been measured during a brief rest period every 3 min as well as superimposed upon the contraction every minute. These experiments have demonstrated that the neuromuscular processes associated with fatigue-related reflex inhibition must be multifaceted and cannot be explained solely by small diameter afferents responding to the byproducts of muscle contraction [38]. Muscular fatigue may be associated with reflex inhibition of the motoneuron pool. However, no literature is available to reveal the possible mechanism explaining the relationship between fatigued peroneal muscle and ankle injury.

Effect of Taping

It has been postulated that prophylactic effect of ankle taping is associated with sensory feedback. By uniting the skin of the leg with the plantar surface of the foot, Robbins et al. [29]

suggested that the sensory cues to plantar surface of the foot are increased, thereby allowing a more accurate foot placement and reducing the changes of excessive ligamentous strain. Karlsson and Andreasson [20] concluded that taping may help patients with unstable ankles by facilitating proprioceptive and skin sensory input to the central nervous system. Therefore, taping or using lace-up brace may contribute proprioception with sensory stimulation. There are some studies emphasizing that ankle taping rapidly loses its initial level of resistance; nevertheless, restraining effect on extreme ankle motion is not eliminated by prolonged activity [25, 27].

Effect of Orthotics and Braces

The various forms of ankle support orthotics and braces available are generally considered effective in providing mechanical stability while restricting joint range of motion. Improvement in proprioception and sensorimotor function has been shown to occur, through stimulation of cutaneous mechanoreceptors near and around the ankle through the application of ankle support [14] and tape [30]. In Sweden, 25 teams with 439 adult male soccer players have been randomized into three groups: those offered a semirigid ankle orthotics (7 teams with 124 players), those offered an ankle disk training program (8 teams with 144 players), and 10 control teams with 171 players. None of the 439 players have been allowed to use taping. Sixty of the 124 players who had been offered the orthosis elected to use it. The rate of sprains had been found to be higher among those with previous history of sprains (25% vs. 11%, $p<0.001$) and among those players without interventions. Both the players who used the orthosis and those in the ankle disk training program had shown significantly lower rates of injury than had done the controls (3%, 5%, and 17%, respectively). This difference had been accounted for entirely by prevention of injury among those with previous sprains [36].

Cordova and Ingersoll [10] have investigated the immediate and chronic effects of ankle brace application on the amplitude of peroneus longus stretch reflex on 20 physically active college students. The results have revealed that the initial application of a lace-up style ankle brace and chronic use of a semirigid brace facilitates the amplitude of the peroneus longus stretch reflex. They also found that initial and long-term ankle brace use does not diminish the magnitude of this stretch reflex in the healthy ankle. This may provide more evidence that the external ankle support offered may enhance cutaneous feedback in addition to the mechanical properties of the devices. Because the lace-up brace covers more area than the semirigid brace, more receptors may be stimulated. Cordova et al. [9] have provided a comprehensive review of the literature regarding the role of external ankle support on joint kinematics, joint kinetics, sensorimotor function, and functional performance. The authors maintain that the effects of ankle support on joint kinematics during static joint assessment and on traditional functional performance measures (i.e., agility, sprint speed, vertical jump height) are well understood. However, they argue that the potential effects of ankle support on joint kinetics, joint kinematics during dynamic activity (e.g., a cutting maneuver), and various sensorimotor measures are not well known and future research investigating the role of external ankle bracing needs to focus on these areas.

Proprioceptive Training for Prevention

There are several discussions about the possibilities for prevention of a soccer injury such as; warm-up with more emphasis on stretching, regular cool-down, adequate rehabilitation with sufficient recovery time, proprioceptive training, protective equipment, good playing field conditions, and adherence to the existing rules [19]. Among these, proprioceptive or neuromuscular training is strongly emphasized in the latest reviews and researches [26, 31, 32, 36]. Assessing the best injury prevention strategies for soccer requires a complete understanding of the factors that contribute to both the occurrence of these injuries and the uptake of, or compliance with, potential prevention strategies [28].

The concept of doing proprioceptive exercises to regain neuromuscular control initially was introduced in rehabilitation programs. It was considered that because mechanoreceptors are located in ligaments, an injury to a ligament would alter afferent input. Training after an injury would be needed to restore this altered neurologic function. Neuromuscular conditioning techniques have also been advocated for injury prevention. Increased postural and movement accuracy increases the consistency with which activities can be performed safely [35].

An intervention program consisting of injury awareness information, specific technical training and a program of proprioceptive training for players with a history of ankle sprains, demonstrated a 47% reduction in the incidence of ankle sprains in the course of single season. Studies have also shown that proprioceptive training not only reduces the risk of reinjury, but also the incidence of acute lateral ankle sprain if used prophylactically [3].

Proprioceptive Training for the Knee Joint

Reconstructing the ACL seems to improve afferent input needed for functional joint stability, and histological studies have shown a repopulation of mechanoreceptors in ACL graft tissue [16]. Exercises to enhance motor control therefore are essential after an anterior cruciate ligament reconstruction. In the past several years, there also has been a heightened awareness of the need for preseason sport conditioning to focus on lower extremity balance and conditioning to attempt to diminish the incidence of knee ligament injuries. Neuromuscular training incorporating plyometrics and agility drills and stressing the need for proper technique for pivoting, shifting, and landing has been advocated to decrease the incidence of ACL injuries. Griffis (quad–cruciate interaction), Henning Sportsmetrics (a three-part prevention consisting of stretching, plyometrics, and strengthening drills), Caraffa (a five-phase progressive skill acquisition program), and Santa Monica by Mandelbaum (a five-part program designed to improve strength, flexibility, injury awareness, plyometrics, and agility skills) are some of the program examples successfully implemented in rehabilitation [16].

Proprioceptive Training for the Ankle Joint

Tropp [34] found that wobble board training during a 10-week period could improve pronator muscle strength in patients with functional instability. Further training has not been found to give any added effect. Wester et al. [39] have conducted a similar study on 48 patients (24 training and 24 no training group) with residual functional instability due to Grade II ankle sprain. Compared to no training group, 12-week training group showed significantly fewer recurrent sprains in a 230 days follow-up period. Eils and Rosenbaum [12] have carried out a research on 30 subjects to find the effects of a 6-week multi-station proprioceptive exercise program. Joint position sense, postural sway, and muscle reaction times showed significant improvements following to this multi-station training program consisting of 12 different exercises (on mat, swinging platform, air squab, eversion-inversion boards, ankle disc, mini trampoline, step, uneven walkway, hanging and swinging platforms, and with exercise bands). The program has been conducted in a way that each exercise was performed for 45-s followed by a 30-s break where subjects move over to the next station.

Proprioceptive Exercises

Although many companies sell fairly complex computerized equipment to help improve proprioceptive input and balance, such training can also be accomplished through various simple drills done on various surfaces with eyes open and eyes shut, progressing from a double to a single limb stance. However, if available, such technologically advanced devices can also be used in proprioceptive trainings and rehabilitation programs. Exercises should include repetitive, consciously mediated movement sequences performed slowly and deliberately as well as sudden, externally applied perturbations of joint position to initiate reflex, “subconscious” muscle contraction [17].

Balance Training

One major category of proprioceptive exercise is balance training. These exercises help to train the proprioceptive system in a mostly static activity. In the lower extremities, activities can include one-legged standing balance exercises, progressive use of wobble board exercises, and tandem exercises in which a postural challenge (e.g., perturbations) can be applied to the individual by the therapist.

Plyometric Exercises

Plyometric exercises incorporate an eccentric preload (a quick eccentric stretch) followed by a forceful concentric contraction. This exercise technique is thought to enhance reflex joint stabilization and may increase muscle stiffness. It has become increasingly popular as an example of neuromuscular control exercise that integrates spinal and brain stem levels and has been an effective addition to upper and lower extremity conditioning and rehabilitation programs [35]. As with the ankle and knee, plyometric exercises are added after near-normal strength in all targeted muscles has been achieved.

Isokinetic Exercises

Isokinetic exercises can be performed to enhance joint position sense using isokinetic devices. The athlete places his/her extremity in a predetermined position and is asked to reproduce this position, initially with the eyes open and then with eyes shut to block visual cues that might aid in neuromuscular control. This exercise can be performed with and without eccentric and/or concentric loads.

Kinetic Chain Exercises

Closed-kinetic-chain exercises challenge the dynamic and reflexive aspects of proprioception in the legs and feet. During a closed-chain movement at onejoint, a predictable movement at other joints is produced, usually involving axial forces.

The lower extremities function in a closed-chain manner during sports and daily life activities, so these exercises will facilitate in regaining the proper neuromuscular patterns.

Leg press, squat, circle running, figure eights, single-leg hops, vertical jumps, lateral bounds, one-legged long jumps, and carioca (crossover walking) are some examples. In the upper extremities, application of graded, multidirectional manual resistance by a physiotherapist can provide proprioceptive feedback in a closed-chain fashion. Open-chain manual resistance exercises with rhythmic stabilization (rapid change in direction of applied pressure) are also considered proprioceptively useful. In either case, resistance can be modified, depending on pain tolerance, as the patient progresses.

Reaction Time

The length of reaction time indicates that motor activity cannot be regarded solely in response to environmental stimuli. In order to prevent injuries, a stored set of muscle commands is necessary. This motor programming allows the initiation of activity on exposure to unfolding event. The repetition of such exercises also enables the cerebral cortex to determine the most effective motor pattern for that task and potentially decrease the response time [35].

Sport-Specific Maneuvers

A very good example for sport-specific maneuvers for prevention programs, "The 11" was developed by FIFA's medical research center (F-MARC) in cooperation with a group of international experts [19]. The exercises focus on core stabilization, eccentric training of thigh muscles, proprioceptive training, dynamic stabilization, and plyometrics with straight leg alignment. The benefits of the program include improved performance and also injury prevention.

In summary, for constructing programs with the aim of prevention, one should incorporate exercises that improve joint motion sense, increase awareness of joint motion, enhance dynamic joint stability, and improve reactive neuromuscular control.

Progression of a program should be designed to proceed from easy to more difficult movements as the pain during the exercises tolerated in time [37] (Tables 1 and 2).

It is generally recommended to continue such a program for at least 6–10 weeks in order to improve proprioceptive abilities, *especially during preseason*. It should also be remembered that proprioceptive exercises should incorporate with other specific training items such as strength, flexibility, agility, etc. during workouts [13].

Table 1 Progression of proprioception exercises

EASY Double leg	DIFFICULT Single leg
Standing position (on the floor)	Moving platforms and different surfaces, for example, pneumatic or foam pads
Single direction (e.g., rocker board, ankle inversion-eversion boards, ankle flexion-extension boards)	Multidirection (e.g., ankle disk, mini trampoline)
Eyes open	Eyes shut
Free hands	Fixed arms (crossed over the chest)
Straight leg	Flexed knee
Fewer repetitions and sets	More repetitions and sets
Simple drills (e.g., walking, stepping down and up)	Complicated drills (e.g., hops, jumps, perturbations, and plyometrics)

Table 2 General principles of a proprioceptive training program

Number of exercises:	2–5
Number of repetitions of exercises:	10–15
Number of sets:	1–3
Duration of total proprioceptive training:	5–15 min (shorter for prevention, longer for rehabilitative purposes), *Preferably every training day (at least 3–5 days a week)*

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