Sports Injuries and Proprioception: Current Trends and New Horizons

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Introduction

The role of proprioception has become increasingly clear in the etiology, prevention, and treatment of sports injuries. It has been generally believed that proprioceptive loss increases the incidence of injury but proprioceptive rehabilitation decreases that and improves the results of treatment [22, 40, 41]. Furthermore, it was also shown that sportive performance could be improved by proprioceptive rehabilitation in uninjured and injured athletes [23, 35]. Recently, there has been significant amount of investigation about the importance of proprioception (Fig. 1).

Proprioception has been investigated in different types of joint injuries [11, 12, 20, 24, 32]. Most of these studies showed that the proprioceptive quality deteriorated following sports injuries [23, 32]. Not only acute injuries but also chronic sequels of acute injuries and overuse syndromes have been shown to lead to diminished proprioception [2, 21, 29]. Although decreased level of proprioception has been observed following different types of sports injuries, it is not clearly known whether injured patients have normal level of proprioception before the injury. Muaidi et al. [28] compared the proprioception of the Olympic level soccer players with non-athletes and observed that highly trained athletes possess enhanced proprioceptive

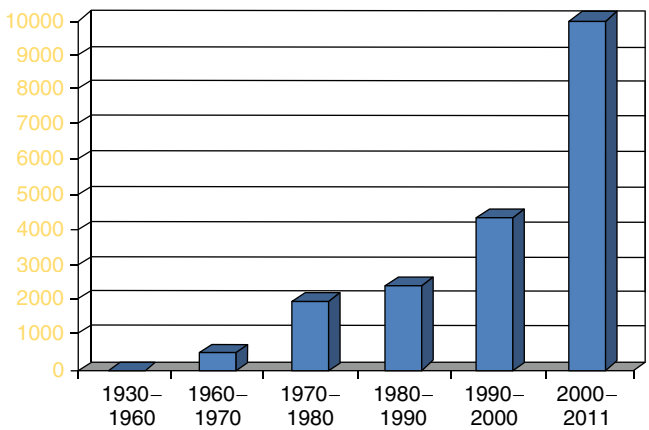

Fig. 1 Numbers of published studies including the word proprioception in their text as per years

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ability. Similar observations were also made by other authors in various types of sports [25, 38]. On the other hand, Schmitt et al. [37] found no improvement in ankle joint position sense after 5 months of ballet training. In our opinion, the design of the above-mentioned studies does not permit to clarify whether the enhanced proprioceptive ability is due to the training or whether it is congenital. This is still an unanswered question and prospective studies are needed to answer it. To our knowledge, no study exists in the literature evaluating the proprioceptive level before the injury. Fort his purpose, the proprioceptive level should be tested first, and then the subjects should be monitorized for having an injury by years; when an injury occured, the proprioception should be measured again to compare it with the preinjury proprioceptive level. However, the normal level of proprioception is not known. We discuss below the controversies about the proprioceptive measurements, and inexistence of a standard proprioceptive screening method that is accurate, sensitive, and reproducible. Because of difficulty in planning such a study and existing problems of proprioceptive measurements, it does not seem to be possible to compare preinjury level of proprioception to post injury level.

Unknown Issues of Proprioceptive Process

Although there are plenty of studies, a lot of unknown matters exist about the proprioception issue. First of all, the mechanism of proprioception is still unknown completely. There are a lot of studies investigating the proprioceptive process, pathways, underlying mechanisms, and the data about the details of the proprioceptive process are increasing. But it is still unknown, how many mechanoreceptors are activated by the external or internal impulses, which pathway(s) are activated during the perception and reaction processes. Exact roles and effects of visual and vestibular systems, amount and physiology of their contribution to a specific condition are also unknown. Also the effect of contralateral extremity or different portions of the body are still unclear.

Measurements of Proprioception

A lot of measurement methods of proprioception have been defined in the literature. Based on these measurements, scientists comment on the proprioceptive status in some specific conditions. Is the proprioception influenced by braces, elastic bandages, surgical or conservative treatments; has the increased proprioception decreased the incidence of injury and enhanced the sportive performance; the aim is to answer these and other questions about proprioception by measuring the proprioception with different methods. However, to measure the proprioception is difficult and cannot be done directly. Thus, the testing conditions are not the same as that of the instant of injury. Patients are usually in supine position, and their extremity is positioned in a computerized system for proprioceptive measurements. Non weight-bearing and static positions are not relevant to the injury position in the real life. Hence, it is doubtful that the existing measurement techniques and their results can reflect the real status of proprioceptive level in injured or uninjured persons.

Another important issue on testing methods of proprioception is that they are not specific to a tissue, a ligament, capsule, or a joint. For example, during a knee joint evaluation, the test results may be influenced by the pathologies of hip joint and/or ankle in almost all measurement techniques. Thus no test method can evaluate the proprioception separately when accompanying lesions are found in the same joint.

According to the above mentioned problems, there are a lot of reports having the controversial results in the same injury patterns. In our opinion, because of the doubtful validity of the current measurement techniques some authors found unchanged [27] and some increased [19] proprioceptive levels in the similar conditions. Thus, incompatibility of the measurement methods of proprioception has been stressed previously [14], and investigations to find an ideal testing method are continuing [3–5, 30].

Because of these above mentioned deficiencies of proprioceptive measurements, we designed some studies investigating the effectiveness of new testing methods [3, 4]. While constituting the hypothesis of the first study, we emphasized the fact that patients are usually kept in a supine position or seated in equipment like dynamometer in most of the proprioceptive measurement techniques. However this position does not reflect the symptomatic or traumatic instant in real life. Furthermore, awareness of the patient from the amount of pressure in the weight-bearing position should be directly related to his proprioceptive ability. Thus we tested the weight bearing sense in patients with patellofemoral pain syndrome [3]. Patients were instructed to weight bear on a scale until reaching the target weight. We selected three different target weights: 10, 20, and 30 kg. Errors from the target weight were noted and compared to healthy controls. Patients with (PFPS) PatelloFemoral Pain Syndrome showed significantly increased errors than healthy controls [3]. To our knowledge it was the first study testing the availability of weight bearing sense for proprioceptive measurement, and we concluded that the new technique presented here may be used for proprioception testing [3].

In other two studies, we evaluated the vibration sense as a proprioceptive measurement method [4, 9]. Vibration sense and related neural pathways seem to be important as well as other deep senses for the perception of a motion or position of a joint. The trigger point of our study was that the current proprioception measurement methods were not specific to a tissue such as anterior cruciate ligament or menisci. We aimed to

evaluate the availability of vibration sense as a proprioceptive test in patients with a clinical diagnosis of patellofemoral pain syndrome and in patients with a medial meniscal tear, in two different studies [4, 9]. *In the first one*, 19 patients with a clinical diagnosis of patellofemoral pain syndrome (PFPS) and ten healthy controls were included in the study [4]. Symptomatic and non symptomatic knees of the patients and both knees of the volunteers were evaluated by the joint position sense (JPS) test and perception times of vibration sense (VS) were measured. A digital goniometer and 128 Hz frequency tuning fork were used for the measurements. Perception time of vibration was 7.23 ± 1.27 sc for the symptomatic knee of the patients, whereas it was 9.08 ± 1.53 sc for contralateral knees ($p < 0{,}05$). JPS testing also showed deterioration of proprioception in accordance with the vibration testing. Similar differences were obtained between the pathologic knee and the normal knees of healthy controls ($p < 0.05$). Results of the study showed that the perception time of vibration is diminished on symptomatic knees of the patients as compared to healthy. We believe that these results, may give rise to the thought that vibration sense may be used for tissue specific proprioceptive measurement [4]. *In the second one*, the study group consisted of 20 patients with isolated medial meniscal lesion and 20 healthy controls who had no experience of knee injury or disorder [9]. Perception time of vibration (PTV) was measured using a tuning fork with a frequency of 128 Hz (RIESTER®). Medial and lateral joint lines were drawn and divided into three parts (front, middle, and posterior). Midpoint of each part was marked for embedding of the tuning fork. Patients were instructed to indicate the time when they no longer percept the vibration and the chronometer was stopped at this moment. Thus, perception time of vibration (PTV) was obtained.

Preoperative measurements of patient group showed longer PTV in posterior part of medial joint line in the pathologic knee (MP), which are also concordant with the arthroscopically proved location of the meniscal tear [9]. Mean perception time of vibration was 13.25 ± 3.46 sc in group I at MP, but it was 9.92 ± 2.0, 9.82 ± 2.8, and 9.93 ± 3.0 sc at the same target point in normal knee of the patients and left and right knees of external control group, respectively ($p < 0.01$) [9]. This study demonstrated that presented technique for measurement of perception of vibration was accurate and reliable [9].

How Proprioception Can Be Improved?

This is one of the most commonly asked questions among investigators. Many internal and external factors which are believed to have a positive effect on proprioception are tested in healthy controls and patients with different clinical scenarios. The effect of proprioceptive rehabilitation techniques on the performance of an athlete in a specific sport is believed to be an attractive research area for scientists [7, 9, 18, 33]. Effects of elastic bandages, taping, braces, surgeries, and other factors were extensively investigated during last decades. Although some promising results were obtained, no clearly useful, standard and reproducible technique was developed for proprioceptive improvement. The investigations to improve the proprioceptive quality still continue, and this is the main reason for current efforts. Correlation between proprioception and other performance criteria such as muscle strength, balance, and laxity might be studied more in the coming years [23]. In a most recent study, Casadio et al. [8] have investigated the effect of robotic training for proprioception enhancement in stroke patients. They tested some selected tasks with a robotic system, by adding the assistive force component [8]. According to the obtained results, they suggested that robots may be useful in neuromotor rehabilitation by combining the repeatable sensorymotor exercises, continuously monitoring the actual motor performance and allowing to create new and controlled haptic environments in which patients can learn to move by only using proprioceptive information [8].

Cameron et al. [6] investigated the effect of neoprene shorts on leg proprioception in football players. They found improvement in some parameters of neuromuscular control ability by wearing close-fitting neoprene shorts. Their results can be concluded that incidence of sports injuries may be reduced by wearing some specially designed shorts, sneakers etc.

We investigated the effect of hot application on knee proprioception in healthy controls and in patients with patellofemoral pain syndrome, in two different studies [1, 31]. *In the first study* the effect of single dose of hot application on the knee joints of the healthy controls was evaluated [31]. The study was conducted on the students of the College of Physical Education and Sports. The study group consisted of 14 male and 13 female students with a mean age of 22.2 ± 2.5 years (range: from 19 to 28 years). Proprioceptive level was measured before hot application on both knees with the technique of active joint position sense using a digital goniometer. Then, with 1 week interval, following 10 min of hot application same measurements were repeated. Proprioceptive capability significantly improved after hot application especially in further flexion angles of the knee. Results of the study showed that hot application increases the proprioceptive capability of the knee. We concluded that these findings should be considered in planning preventive and therapeutic strategies for sports injuries [31].

In a complementary fashion, we planned *the second study* that the proprioceptive status was monitored in patients with patellofemoral pain syndrome with or without hot application during their standard treatment protocol [1]. First group patients underwent home exercises only; second group ones same exercises plus hot application. Hot was applied three times a day, and 20 min for each session. Proven proprioceptive deficiency improved better in exercise plus hot application than exercise treatment only [1].

Other Areas for Proprioceptive Researches

Proprioception seems not to be related to only sports injuries. It is gradually understood that a lot of body functions are directly related to proprioceptive capability. In a recent study, it is suggested that proprioception has an important role in handwriting [15]. Writing characteristics were quantified by using a digital writing tablet with and without visual control [15]. According to the results obtained they believed that morphological aspects of handwriting need intact proprioception. Kessiby et al. [13] reported the results of proprioceptive education for hand orientation in blind subjects. Their findings provided the first evidence of an automatic online correction mechanism for hand orientation guided only by proprioceptive inputs reaching in blind subjects [13]. In another study, Horlings et al. [16] investigated the vestibular and proprioceptive contributions to human balance corrections. They believed that proprioception is important for movement strategies and synergies, whereas vestibular functions are more active in modulation depth [16]. They also stressed that proprioceptive loss leads to changes in both movement strategies and synergies [16]. In another interesting study reported by London et al. [26], authors tried to instruct a behaving monkey by electrical stimulation of proprioceptive cortex. They demonstrated that a monkey can learn to detect such stimuli and recognize the frequency of a given stimulus, based on memory of previous stimuli [26]. Effect of whole body vibration on muscle strength and proprioception was investigated by Trans et al. [39]. They suggested that exposure of vibration exercises on a stable platform yielded increased muscle strength and proprioception [39]. Riva et al. [34] designed a study for the prevention of muscle atrophy and osteoporosis for astronauts by using high frequency proprioception. They pointed out the difficulty in applying active exercises during space flights and accordingly occurrence of muscle atrophy and osteoporosis [34]. They verified the whether an electrical system creating high frequency proprioceptive inputs reachable on the earth in microgravity conditions [34]. They postulated that high frequency proprioceptive flows could be useful for the prevention and recovery of muscle atrophy and osteoporosis [34]. Effects of proprioceptive training were also investigated in musician's dystonia and writer's cramp [36]. Another interesting report came from University of Pittsburg in April 2008. Researchers of this university created a human performance research laboratory for naval special warfare [17]. Researchers aimed to reduce the incidence of preventable musculoskeletal injuries during training, combat, and recreation; to enhance force readiness, reduce fatigue, and optimize performance; and to prolong the operational life [17]. All above mentioned fields of interest show that proprioception is not related only to sports injuries. Enhancement of knowledge about proprioception seems to be useful for many aspects of daily life.

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