CAN PROPRIOCEPTION BE IMPROVED BY EXERICSE?

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The study examined if regular exercise with high demand in postural control and cyclic exercise could improve proprioception of the foot and ankle complex. A total of 38 young health people with different exercise habits for more than five years formed three groups: the ice hockey, running, and sedentary groups. Kinesthesia of the foot and ankle complex was measured in plantarflexion (PF), dorsiflexion (DF), inversion (IV) and eversion (EV) at 0.4°/s passive rotation velocity using a custom-made device. The results showed that the hockey group had significantly better kinesthesia in PF/DF, IV/EV than did the running and sedentary groups. The running group did not show better kinesthesia compared with the sedentary group. It is concluded that propiorception of foot and ankle complex can be improved by long-term exercise that has high demand for postural stability, such as ice hockey.

KEYWORDS: foot and ankle joint complex, kinesthesia, running, hockey

INTORDUCTION:

Proprioception is the sensory feedback that contributes to conscious sensation (muscle sense), total posture (postural equilibrium), and segmental posture (joint stability), and is mediated by proprioceptors that are located in the skin, muscles, tendons, ligaments, and joint capsules (Lephart, Pincivero, Giraldo, & Fu, 1997). Research has shown that postural control stability is significantly affected by proprioception in the lower limb (Lord, Clark, & Webster, 1991). Colledge et al. (1994) studied the relative contributions to balance of vision, proprioception, and the vestibular system with age by measuring body sway during standing. In four different age groups through 20 to 70 years old, the relative contribution of each sensory input was the same, with proprioception being predominant throughout each age group. Moreover, the lack of proprioceptive feedback that results from injuries, such as ankle injury (Guskiewicz & Perrin, 1996), may allow the excessive or inappropriate loading of a joint (Co, Skinner, & Cannon, 1993), and is one of the factors that leads to progressive degeneration of the joint and continued deficits in joint dynamics, balance, and coordination (Riemann & Guskiewicz, 2000). Much clinical research has demonstrated that individuals with proprioception and neuromuscular response deficits as a result of injury, lesions, and joint degeneration are less capable of maintaining postural stability and equilibrium (Cornwall & Murrell, 1991; Forkin, Koczur, Battle, & Newton, 1996; Garn & Newton, 1988; Pintsaar, Brynhildsen, & Tropp, 1996).

Considering the importance of the proprioception in postural stability, movement control, and injury prevention, it would therefore be beneficial to understand the effects of exercise on proporioception function. The foot and ankle complex is a critical structure in postural stability and its injury rate is very high in all sports injuries of the body. To prevent foot and ankle injury, apart from prophylactic devices, exercise training in proprioception is needed to enable athletes to return to preinjury levels of activity following ligament and muscle injuries. However, it is still being debated upon whether exercise training can improve proprioception or not (Ashton, 2001). Some published research works have found that proprioception can be improved through exercise, especially proprioceptive exercise that requires three actions: the proprioception of the joints, balance capacity, and neuromuscular control (Irrgang & Neri 2000; Eils & Rosenbaum, 2001). In particular, long-term Tai Chi practice was found beneficial to the proprioception of the lower limb (Xu, et al. 2004). However, a recently published work which studied the influence of a five-month professional dance training without concurrent additional coordinative training found that such training did not lead to improvements in ankle joint position sense or improved measures of balance (Schmitt et al., 2005). These studies suggest that exercise may benefit proprioception. However, the effect may be influenced by the form and modality of the exercise. To the knowledge of the authors, scientific evidence on the impact of exercise form and modality on proprioception of the lower extremity is lacking. To bridge the research gap, we designed a cross-sectional study to examine the effects of exercise on ankle proprioception in young people through comparison of the passive motion sense, kinesthesia, among three groups, long-term regular ice hockey players, long-term regular runners, and sedentary people. Such efforts would add the understanding in the effects of exercise on proprioception and subsequently contribute to the development of the program in the enhancement of proprioception function in children, elderly people, and patients with deficits of proprioception.

METHODS:

Subjects: A total of 38 young healthy people were recruited based on their exercise habits. For the first group, 12 people (6 males, 6 females) with a regular running habit, running for more than three times each week for more than five years, formed the running (R) group. The next group, 13 males with an ice hockey playing habit, playing more than three times each week for more than five years, consisted of the hockey (H) group. Finally, 13 people with no regular exercise habit in the past five years served as the sedentary (S) group. The characteristics of the participants are listed in Table 1. All participants were predominantly healthy and they had no history of significant cardiovascular, pulmonary, metabolic, musculoskeletal, or neurological diseases and injuries. An informed consent form was given to each subject prior to participation. This study was approved by the Human Ethics office, University of Ottawa.

Table 1 Subjects characteristics (Mean ± SD)

	Age (years)	Body weight (kg)	Body height (cm)	Body mass index (kg/m^2)
H Group (n = 13, m)	20±0.5	82.5 ± 7.6	180.5 ± 7.0	25.3 ± 2.0
R Group (m = 6, f= 6)	20±1.9	70.1 ± 11.6	171.0 ± 8.4	24.0 ± 4.0
S Group (m=5, f = 8)	21.5±2.5	65.1 ± 8.4	169.3 ± 7.3	22.6 ±1.7

m, males; f, females.

Data Collection: The testing was performed in a well-lit and well-ventilated room. The room was sound-attenuated and isolated so as to reduce any auditory or visual interference that might distract the participants. After being measured for body weight and body height, each subject individually participated in one session of data collection. Data were collected using the instrumentation and procedures described by Lentell et al (1995), but small changes were instituted (Xu et al. 2004). As illustrated in Figure 1, the custom-made device is a box with a movable platform that rotates about a single axis in two directions. With the foot resting on this platform, plantar-dorsiflexion or inversion-eversion of the foot and ankle complex movements can occur. This platform is moved by an electric motor that rotates the foot on an axis at a rate of 0.4° /sec. Movement can be stopped at any time with the use of a hand-held switch. The angular motion achieved by the platform is calculated by the dents that the motor rotates. The device is also equipped with a hanging scale and a fixed pulley supported by a trestle, which is outside the device. A thigh cuff attached to the lower end of the scale is wrapped around the lower thigh of the subjects. Through adjustments of the length of the cuff, the extremity is lifted by the scale and its weight is recorded when a subject fully relaxes his/her thigh. After this, the thigh cuff is attached to one end of the rope around the pulley and the other end is hung with weights. The extremity can then be adjusted to where the foot is in contact with the platform. Through the addition or reduction of the weights, the investigator can standardize and control the amount of the lower extremity weight resting on the platform during testing.

For data collection, each subject was seated on an adjustable chair and his/her dominant foot was so placed on the platform that the axis of the apparatus coincided with the plantar-dorsiflexion axis or inversion-eversion axis of the foot and ankle joint. The hip, knee, and ankle were positioned at 90°, respectively. Fifty per cent of each subject's lower extremity weight was rested on the platform by the use of the thigh cuff suspension system to control unwanted sensory cues from the contact between the instrument and the plantar surface of the foot. During testing, the subjects' eyes were closed to eliminate visual stimuli from the testing procedure and apparatus. Data collected in each test movement began with the foot placed in a starting position of 0°. The subjects were instructed to concentrate on their foot and to press the hand-switch when they could sense motion and identify the direction of the movement. After performing two practice trials, a formal data collection was conducted. The motor was engaged to rotate the foot into dorsiflexion or plantarflexion, or inversion or eversion at a random time interval between 2 and 10s after subject instruction. The researcher recorded the rotation angles of the platform and the direction of movements as passive motion sense. At least 12 randomized trials were conducted: three for movement in each direction. The kinesthesia of plantar flexion and dorsiflexion was measured first. The measurement of the kinesthesia of inversion and eversion followed.

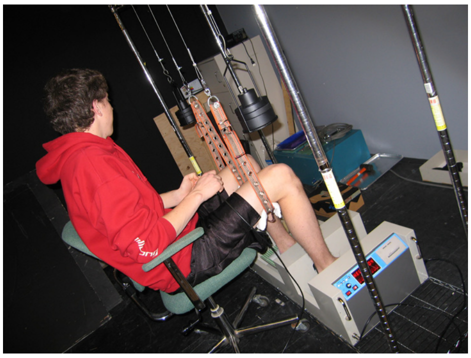

Figure 1 Testing apparatus and a subject positioned for evaluation of passive movement sense of ankle.

Data Analysis: All variables are presented as mean and standard deviation (SD). Independent t-test was used to test if there was any significant difference in the measurement within group. Paired t-test was used to determine if there was any significant difference between the data collected from the dominant and nondominant sides within group. If there was no significant difference, the data from both sides and both genders was pooled together. In each group, values for passive motion sense of foot and ankle complex in paired motions, dorsiflexion vs plantarflexion, inversion vs eversion, were respectively compared using paired t test. One-way analysis of variance was used to estimate significant differences in the values of each passive motion sense of the foot and ankle complex among groups. The post hoc Tukey tests were performed when necessary to isolate the differences and $P \leq 0.05$ was considered statistically significant.

RESULTS:

There are significant differences in body weight and body height between three groups. However, no significant difference in body mass index (BMI) was found among three groups. Ankle joint kinesthesia significantly differed among the three groups ($P<0.01$ or 0.001). 1.93±0.65° Dorsiflexion, 1.92±0.62° plantarflexion, 2.79±0.64° inversion, and 3.17±1.12° eversion were perceived in the ice hockey group, and were significantly smaller than that in the running and sedentary groups. The most remarkably significant differences were found in the measurements in inversion and eversion among the three groups. The ice hockey group was able to perceive the 2.79±0.64° of inversion motion and 3.17±1.12°of eversion motion. The values of the pervieved passive inversion and eversion motion were 4.33±2.04 ° and 4.76±2.59 in the running group, which was 31% to 35% larger than that in ice hockey group. The sedentary group perceived values of passive motion in inversion and eversion larger by 50% to 55% than the values of the ice hockey group. No significant difference was found between the running group and the sedentary control group. Table 2 lists the statistical analysis results of the values of kinesthesia measured in different direction movement in the three groups.

Table 2 Kinesthesia in dorsiflexion-plantarflexion and inversion-eversion in three groups (Mean ± SD)

	Kinesthesia (degrees)	H group (degrees)	R group (degrees)	S group (degrees)
Dorsiflexion	Mean ± SD	1.93±0.65	2.53±0.88	2.47±0.83
	Maximum	3.35	4.64	1.40
	Minimum	1.07	1.30	4.30
Plantarflexion	Mean ± SD	1.92±0.62	2.61±1.12	2.51±0.86
	Maximum	3.14	5.64	4.60
	Minimum	1.07	1.35	1.58
Inversion	Mean ± SD	2.79±0.64	4.33±2.04	5.41±2.71
	Maximum	4.90	7.98	13.23
	Minimum	1.30	1.03	2.59
Eversion	Mean ± SD	3.17±1.12	4.76±2.59	5.18±1.78
	Maximum	6.31	10.15	8.31
	Minimum	1.95	1.22	2.01

DISCUSSION:

The recognition of the effects of proprioception and neuromuscular control on joint and posture stability has led the orthopedic and sports medicine communities toward an emphasis in rehabilitation on the restoration of proprioception to enhance dynamic joint stability (Irrgang & Neri, 2000). However, a few publications examined the impacts of exercise on propriocetpion function, especially on the effects of different forms of exercise. Our study provides the evidence that long-term ice hockey practitioners not only showed significantly better ankle joint kinesthesia than sedentary controls but also that their ankle joint kinesthesia was significantly better than long-term running exercisers. Moreover, long-term regular running exercisers did not perform better in ankle joint kinesthesia compared with their sedentary counterparts.

According to Irrgang and Neri's description (2000), propriocpeitive exercises require to take account of three parts: proprioception of joints, balance capacity, and neuromuscular control. The key of exercise in the successful enhancement of proprioception is to choose the correct forms of exercise to progressively stimulate the demands required during functional activities in which the individual participates. A cross sectional study of examining the kinesthesia of the knee and ankle joint among three groups of elderly people showed that long-term Tai Chi exercisers had significantly better kinesthesia of the knee and ankle joint than long-term runners/swimmers. Moreover, long-term runners/swimmers could not perform better in perceiving the passive motion of dorsiflexion and plantar flexion of ankle joint (Xu, et al, 2004) than did a sedentary group. Tai Chi exercise is a series of individual graceful movements in a slow, continuous, circular pattern. The movements of Tai Chi are gracefully fluent and consummately precise because specificity of joint angles and body position is of critical importance in accurately and correctly performing each form (Jacobson, Chen, Cashel, & Guerrero, 1997). Conscious awareness of body position and movement is demanded by the nature of the activity. Such exercise form contains all components that are needed in training proprioception and benefits proprioception. Eils and Rosenbaum (2001) investigated the effects of a 6-week multi-station proprioceptive exercise program on patients with chronic ankle instability. The proprioceptive exercise included exercise mats, a swinging platform, an ankle disk, exercise bands, an air squab, wooden inversion-eversion boards, a mini trampoline, an aerobic step, an uneven walkway, and a swinging and hanging platform. The results showed a significant improvement in ankle joint position sense tested in weight bearing conditions and postural sway as well as significant changes in muscle reaction times in the exercise group. The results demonstrated that proprioception can be trained by proproceptive exercise. However, a recently published work could not support the effect of exercise training on proprioception. Schmitt and co-worker (2005) studied the effects of 5-month ballet training on ankle position sense. There were 42 dancers with more than 10 years dancing experience in professional training and 40 age-matched and gender-matched controls with no prior dance or specific sport training who participated in the study. Passive angle-replication tests (joint position sense tests) were conducted during the pre- and post-training program. The training consisted of 15 to 16 hours per week of classical ballet and 4.5 hours per week of modern dance, as well as traditional dances, jazz dance, and weight training for men. Howerver, no significant differences in joint position sense were found either in the pre- or post-test of the training program. It is well known that ballet and other dances have a very high demand to proprioception, balance capacity, and neuromuscular control. Ballet training should be considered as a proprioceptive exercise. The possible cause of the undetectable effect of ballet training on proprioception in Schimitt's study may be related to the sensitivity and reliability of the testing method. Beynnon et al. (2000) published their research work in validation of the techniques used to measure knee proprioception. They compared the accuracy, repeatability, and precision of seven joint position sense techniques and one joint kinesthesia measurement technique in normal subjects with no history of knee injury. They found that joint kinesthesia was more repeatable and precise than each of the joint position sense techniques. Moreover, the measurement in weight bearing condition was also more repeatable. Therefore, they recommended that studies designed to evaluate proprioception should consider using kinesthesia, which should result in increased power and sensitivity to detect significant differences, if they truly exist. In Schmitt's study, proprioception was examined by measuring joint position sense under non-weight bearing conditions. The testing method may not have been sensitive enough to detect the proprioception function.

Another factor influencing the impact of exercise on proprioception is the duration of training. Xu, et al (2003) examined the effects of a 15-week Tai Chi exercise program on the proprioception of the knee and foot and ankle complex in elderly people. The Tai Chi exercise program lasted 15 weeks, with three sessions a week, consisting of 1 hour for each session. The results demonstrated that the significant training effect of kinesthesia was found in the knee joint, but not in the foot and ankle complex. The study of Eils and Rosenbaum (2001) showed that 6-week proprioceptive exercise gained effects on the joint position sense in young people. In the study, the subjects trained 20 min each day, and the intensity of the 6-week training period was increased by small modifications every 2 weeks. These scientific evidences demonstrated that exercise form, training duration, and age of the participants, as well as the evaluation method used, should be considered as the examination of the effect of exercise on proprioception.

The present study shows that long-term ice hockey players had significantly better passive motion sense than long-term runners, suggesting that long-term hockey playing results in a training effect in proprioception. Ice hockey is a non cyclic, but fast-paced sport, requiring good levels of skill, speed, agility, and endurance. It has very high demands with regard to postural control capacity, which would contain all components of the proprioceptive exercise. Movements in ice hockey, such as turning, sideward movement, and power stride, put a very big challenge to the ankle and foot complex. Moreover, the very narrow supporting base of the body has a very high demand for balance control capacity. Therefore, the awareness of joint position and movement is always emphasized during ice hockey exercise. Compared with ice hockey, running is a cyclic exercise. The awareness of joint position and movement is not specifically emphasized during this form of exercise. Additionally, most runners

exercise only for the sake of enhancing their health and for recreation; they do not pay much attention to the techniques involved in the exercise, unless awareness of the joint position and angles is especially required in some exercises, such as ice hockey. This might be one of the reasons that the running exercise did not show benefits to knee and ankle kinesthesia in this study. The study conducted by Xu et al (2004) had denoted the fact that old long-term running exercisers did not show significantly better kinesthesia than the old sedentary people. The result of the present study from young health people showed a similar pattern as that in old people. It is suggested that choosing a proper exercise form in designing exercise program for improvement of proprioception is critical.
Since there is no published work reporting the study of kinesthesia measured in inversion and eversion, the present study for the first time profiled passive motion sense in inversion and eversion in the young people with different exercise habits. The ice hockey group had significantly better passive motion sense in inversion and eversion compared with the running and sedentary groups. Moreover, a significant difference in kinesthesia of inversion and eversion from the dominant ankle and foot complex was found in the ice hockey group. The passive motion sense of inversion was significantly better than that in eversion in the hockey group. The cause leading to such difference is unclear. It might be associated to the movement's characteristics and the hockey boot design and lateral longitudinal arch of the foot. Ice hockey movements involve much more medial-lateral movements, which would train the proprioceptors in the foot and ankle. The lateral longitudinal foot arch might be more sensitive to passive motion because of a larger contact area with the contact surface. Additionally the current design of hockey boots provides more stability to the ankle joint and only a very small motion range of the ankle joint is allowed by this footwear. The range of supination of the bare foot inside the boot (between touchdown and maximum) was 12.3 degrees +/- 4.6 degrees in a high-cut hockey boot (Avramakis, Stakoff, & Stussi; 2000). Such hockey boot design and the demand in movement and balance in ice hockey both need muscles, especially the small muscles, to do very fine contraction so as to accurately adjust tension and length. Working muscles in this way would result in training effects on muscle spindles and Golgi tendon organs as well as other proprioceptors.

CONCLUSION:

Long-term ice hockey exercise results in training effects on kinesthesia of the foot and ankle complex. The better passive motion sense was especially significant in medial-lateral direction. Long-term running could not yield the training effects on kinesthesia of the ankle and foot complex in the runners. However, long-term running can improve the passive motion sense in medial-lateral direction, but did not reach a statistical level. The results suggest that proprioception could be improved by exercise. However, exercise form and training duration are critical to gaining training effects.

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