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Rapid repetitive passive movement improves knee proprioception

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ABSTRACT

Background: Proprioception can be affected by many factors including exercise. Most exercises involve certain degrees of repeated passive movements, and different velocities of these movements might affect proprioception differently. The purpose of this study was to evaluate the influences of different angular velocities of repeated passive movement on knee proprioception via active repositioning and kinesthesia measurement.

Methods: A quasi-experimental design with repeated measure on movement velocity (0°/s, 2°/s, 90°/s, and 150°/s). Sixteen healthy young adults participated in the study. All of them received 30 times repeated passive knee movement intervention in four different knee angular velocities – 0°/s, 2°/s, 90°/s, and 150°/s – with counter-balanced sequence in four successive days. Knee active repositioning and kinesthesia were measured with error scores before and after the intervention.

Findings: The results revealed a decrease in error scores in both active repositioning and kinesthesia measurement with the velocities of 90°/s and 150°/s ($p<0.05$); however no significant change was seen with the static condition (0°/s) or with the velocity of 2°/s.

Interpretation: We concluded that repeated passive movement with rapid angular velocities was capable of improving knee proprioception, specifically in active repositioning and kinesthesia measurements. These results would provide information on the effects of different movement velocities onto knee proprioception. Along with further investigations, the findings could potentially enhance our knowledge on knee injury prevention, treatment, and rehabilitation.

1. Introduction

Knee proprioception provides information about knee joint position and movement in space primarily via joint mechanoreceptors, superficial receptors and muscle afferents (Lephart and Fu, 2000). It is essential for people to accomplish daily activities such as walking and running. In disease or injury states such as arthritis or ligament injuries, knee proprioception is impaired (Beynnon et al., 1999). These deficits would affect knee normal biomechanics and thus interfere with daily function and sports performance.

Proprioception is usually evaluated via joint position sense and kinesthesia. Joint position sense measures the ability to reproduce the target angle of the joint tested, whereas kinesthesia measures the threshold to detect joint passive motion. Proprioceptive sensitivities can be affected by many factors. Age, cold temperature, diseases and injuries are found to deteriorate proprioception (Hewitt et al., 2002; Hurley et al., 1998; Marks and Quinney, 1993; Uchio et al., 2003). Gender differences also exist because of hormonal influences (Friden et al., 2006; Henry and Kaeding, 2001). As to the exercises, the effects can be either beneficial or detrimental. The positive effects of exercises on proprioception include the increase of mechanoreceptor sensitivities, caused by better movement control with muscle strengthening, better visco-elastic properties of muscular tissue, enhanced oxygenation and increased body temperature (Bartlett and Warren, 2002; Bouet and Gahery, 2000; Roberts et al., 2004; Xu et al., 2004); or the plastic changes induced in the cortex, caused by repeated positioning of body and limb joints in specific spatial positions (Roberts et al., 2004; Xu et al., 2004). The negative effects of exercises often involve joint proprioception deterioration during fatigue state, in which the metabolic products of muscular contraction directly impact the discharge pattern of muscle spindles and disrupting afferent feedback (Marks and Quinney, 1993; Miura et al., 2004; Ribeiro et al., 2007); and proprioception deterioration due to ligament laxity caused by repetitive passive movements and tractions (Lattanzio and Petrella, 1998). Whether the effect of a particular exercise is positive or negative depends on its mode, frequency, duration and intensity.

The possible mechanisms of exercises onto proprioception discussed in the above studies can be categorized into an active and

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a passive component. The active component was driven by the repetitive active muscle contractions and motor programming. The passive component resulted from the repetitive passive movements and tractions onto the joint during the exercise. Since proprioception gathers the information not only from the muscle afferents, but also from the joint mechanoreceptors and cutaneous receptors; the passive component of exercises must also play a role in influencing proprioception. Clinically, a continuous passive motion device is used extensively after knee joint surgery for gradually restoring range-of-motion and preventing contracture by repetitively moving the joint. However, the effects of the repetitive passive joint movement onto proprioception have seldom been valued or investigated.

To date, two journal papers were found to directly evaluate the influence of repetitive passive movement onto proprioception. One study by our research group (Ju et al., 2010) examined the effects of repetitive passive movement onto proprioception. Subjects' knee joints in the study were passively moved in flexion–extension with an angular velocity of 120°/s for 60 repetitions. This movement was provided by Cybex system (Cybex NORM Testing and Rehabilitation System, Computer Sports Medicine, Inc., Stoughton, MA, USA). The results revealed that repetitive passive knee joint movements were capable of enhancing knee joint proprioception. The second study was by Friemert et al. (2006), who examined the effect of continuous passive movement upon joint position sense in patients with anterior cruciate ligament injury (Friemert et al., 2006). Their continuous passive movement was provided by a continuous passive motion device, which usually moved in a speed of 2–15°/s. Their results indicated subjects' knee proprioception improved, however it did not reach a significant level.

The two above-mentioned studies highlighted the underlying positive effects on repetitive passive movements on proprioception. The authors noticed a difference in the speed of the repetitive passive movement in these two studies. One study chose a speed of 120°/s, and the other chose a relatively slow movement speed of 2–15°/s. Movement speed is related to other exercise parameters including mode, duration and intensity, and it could affect proprioception. However, to what extent the movement speed of the passive movement affect proprioception needs to be investigated. The purpose of this study is to evaluate the effects of repetitive passive movement at different angular velocities on knee proprioception. We hypothesized that various speeds of repetitive passive movement intervention would affect knee proprioception differently.

2. Methods

This crossover study measured the influences of different movement angular velocities on knee proprioception. The independent variable was the repetitive passive movement angular velocity (4 levels: 0°/s, 2°/s, 90°/s, 150°/s). The velocity of 0°/s was used as the control, and 2°/s was chosen to mimic the angular velocity of the clinical-used continuous passive motion device. Angular velocities of 90°/s and 150°/s were frequent-used velocities with Cybex, and they were about the knee angular velocities during foot flat and heel strike in a gait cycle (Richards and Thewlis, 2008). They served as the faster movement velocities for the purpose of comparison. The dependent variables included knee repositioning error for joint position sense and threshold to the detection of passive movement (TTDPM) for kinesthesia.

2.1. Subjects

Sixteen healthy young volunteers participated in this study (eight males and eight females, mean age 22.1(SD 2.63) years). Subjects with a history that might interfere with the experiment, including 1) lower extremity diseases or dysfunction; 2) knee injuries within the past six months; 3) neuromuscular coordination impairments; 4) sensation deficits; 5) currently taking pain killers or anesthetics, were excluded. All participants provided written informed consent. This study was approved by the Institutional Review Board of Chang-Gang Memorial Hospital. Subject's dominant leg, which was determined by asking the subject which leg they would predominantly use to kick a ball, was designated as the test leg. All subjects were right leg dominant.

2.2. Equipment

The equipment utilized in this study included a continuous passive motion device (FlexMate K500, BREG, Inc., Vista, CA, USA), an isokinetic dynamometer (Cybex NORM Testing and Rehabilitation System, Computer Sports Medicine, Inc., Stoughton, MA, USA), an electrogoniometer (SG110, Biometrics, Ltd, Cwmfelinfach, Gwent, UK) and a self-designed device for measurement of knee joint proprioception. This device consisted of pulleys driven by a motor with an angular deflection of 0.5°/s, a string attached to the pulleys and a rotary disk, a side bar driven by torque of the rotary disk to initiate lower leg movement, a control box and a back-adjustable metal sitting frame. The test–retest reliability for this device was evaluated for four consecutive days with ten healthy individuals (mean age 23.4(SD2.3) years, height 165.9 (SD10.2) cm, weight 60.0(SD12.4) kg). The ICC (Intraclass correlation coefficient) for AES was 0.981, with a 95% confidence interval between 0.951 and 0.995.

Continuous passive motion (CPM) device was used to provide the repetitive passive movement to the knee joint at a speed of 0°/s and 2°/s. Since this device could only move at relatively slow speeds (up to 2.5°/s), the isokinetic dynamometer was used to provide the repetitive passive movement to the knee joint at the speeds of 90°/s and 150°/s. The electrogoniometer was used to measure the flexion–extension of the knee, and the self-designed device was used to assist knee proprioception measurement by moving the extremity to the desired angle.

2.3. Protocol

Subjects were seated in a comfortable position, with back fully supported by the backrest and lower limbs hanging freely over the side of the metal frame. They were blindfolded, wore an earphone headset and an air splint to remove feedbacks from sensory channels other than proprioception. The electrogoniometer was taped to the lateral side of the knee. Subjects were given the control box and instructed to depress the on/off switch when they perceived movement of the extremity being tested (Fig. 1). Knee proprioception was measured via active repositioning and kinesthesia testing error scores. Active repositioning was evaluated via subject's ability to reproduce specific knee angles around 30°–60°flexion by random selection. To start with, the subject's leg hung freely on the edge of the metal frame. From the starting position, the subject's leg was moved to a specific angle for five seconds and then returned to the starting position. After 10 s, the subject was asked to reproduce that particular angle. For kinesthesia measurement, the starting angle of the knee was around 30°–60° flexion. The subject's leg was moved passively in an angular deflection of 0.5°/s to either flexion or extension (each direction was moved three times). The subject was asked to depress the on/off switch when he/she perceived movement of the extremity being tested, and to report the perceived movement direction. Active repositioning, kinesthesia measurement to flexion and kinesthesia measurement to extension were all conducted three times. A 20-second rest was provided between tests.

Following the measurement of proprioception, each subject received 30 times repeated passive knee movement intervention. The velocity of movement was predetermined. After the movement intervention, the subject underwent knee active repositioning and kinesthesia testing again for three trials.