J. Phys. Ther. Sci.
25: 587–590, 2013

The Effect of Repetitive Passive and Active Movements on Proprioception Ability in Forearm Supination

OhSung Kwon, PT, MPT[1,2)], SeungWon Lee, PT, PhD[1)]*, YoungWoo Lee, PT, PhD[1)], DongKwon Seo, PT, MPT[1,3)], SangWoo Jung, PT, MPT[1)], WonJae Choi, PT, MPT[1)]

[1)] *Department of Physical Therapy, College of Health and Welfare, Sahmyook University, Hwarangro 815, Nowon-gu, Seoul 139-742, Republic of Korea. TEL: +82 2-3399-1630, FAX: +82 2-3399-1639*
[2)] *Department of Physical Therapy, Seonam University*
[3)] *Department of Physical Therapy, Sun Moon University*

Abstract. [Purpose] This study was conducted in order to investigate the effect of repetitive passive movement and repetitive active movement on proprioception in forearm supination. [Subjects] This study had a cross-sectional design. Twenty-three right-handed healthy subjects were recruited. All subjects randomly received both repetitive passive movement and repetitive active movement (repetitive passive/active movement at 120°/s with 60 repetitions over a 0–80° range). Active and passive joint repositioning of all subjects was measured using the error score for position sense, both before and after repositioning intervention. [Results] In the repetitive passive movement test, there was a statistically significant decrease in the pre- versus post-repositioning error scores in the active and passive angle examinations. In the repetitive active movement test, there was a statistically significant increase in pre- versus post-repositioning error scores in the active and passive angle examinations. In the comparison of position sense, there was a statistically significant decrease in both active and passive angle repositioning error scores in repetitive passive movement versus repetitive active movement. [Conclusion] Repetitive passive movement improved the proprioception results for forearm supination, compared to repetitive active movement. Results of this study indicate that repetitive passive movement can be recommended to clinicians for rehabilitation therapy as it provides greater proprioception benefits.
Key words: Joint position sense, Repetitive passive movement, Proprioception

(This article was submitted Dec. 3, 2012, and was accepted Dec. 29, 2012)

INTRODUCTION

The primary outputs of muscle function at the elbow and forearm include elbow flexion and extension, and forearm supination and pronation[1)]. The rotation of the forearm, as in pronation and supination, are important motions used in everyday life in performing tasks such as turning keys or door handles, bringing food to the mouth and performing personal hygiene activities[2)]. The forearm muscles involved in rotation include the supinator, biceps brachii, extensor carpi radialis, brachioradialis, extensor pollicis longus and abductor pollicis longus. In particular, the actions of the supinator and biceps brachii muscles produce the supination motion[3)]. The action of these muscles greatly affects the stability of the elbow[4)]. Maintaining the safety of the joints requires that they return to their proper position after movements, and that they maintain their integrity with minimal movement. The process of proprioception has a fundamental effect on the stability of the joints and in balance control[5, 6)]. Proprioception enables safe human movements in daily activities and sports. The proprioception process involves muscle spindles, Golgi tendon organs, articular and cutaneous mechanoreceptors, and enables position sense, movement sense and force sense[7)]. In a position-matching task, position sense measures the target angle of the joint that is tested.

The output of proprioception therapy can be affected by therapeutic exercise type. The exercises used in proprioception therapy are divided into active and passive components[8)]. Most clinical studies have found that exercise affects proprioception ability.

Baek et al.[9)] reported that repeated passive exercise was beneficial for improving proprioception. Ju et al.[10)] concluded that repeated passive exercise resulted in a significant improvement of joint position sense. However, Lattanzio and Petrella[11)] suggested that repetitive passive movements deleteriously affect of proprioception capabilities.

Hazneci et al.[12)] reported that isokinetic exercises positively affected passive position sense, the stabilization of joints and proprioceptive acuity. Active exercises such as *tai chi* have been found to decrease position errors in subjects completing a position matching task[13, 14)]. However, Ju et al.[8)] found that repetitive active exercise had a nega-

*To whom correspondence should be addressed.
E-mail: swlee@syu.ac.kr

tive impact on joint proprioception. Other experimental studies have shown that active exercises negatively affect proprioception because exercise fatigue can disturb position sense[15, 16].

Several studies have been performed on elbow and forearm proprioception, but most of these were conducted in order to evaluate flexion and extension[15, 17, 18]. Although forearm supination is very important for the proper functioning of the upper limbs, there have been few scientific studies on this topic, and studies of proprioception are rare. Therefore, this study was conducted in order to investigate the effect of repetitive passive movement (RPM) and repetitive active movement (RAM) on the proprioception capabilities involved in forearm supination.

SUBJECTS AND METHODS

A total of 23 healthy right-hand dominant volunteers participated in this study (Table 1). The inclusion criteria for the subjects were as follows: no upper extremity diseases, no sensory deficits, no limited range of motion (ROM) of the upper extremities, no psychological or emotion problems. The study protocol was approved by the institutional review board of Sahmyook University.

For the repositioning test of supination position sense in the right forearm, we used a Biodex (Biodex Multi-Joint System 2, Biodex Corp, NY, USA) which includes an electrogoniometer which is sensitive to 1° increments. All assessments were performed with the subjects blindfold and seated on a chair. The subjects' trunks were strapped to the chair to prevent unwanted motion. Proprioception was measured in terms of passive and active repositioning. The starting position of measurement was the elbow flexed at 90°, midway between pronation and supination. In this starting position, the Biodex device display unit was set to 0°.

Position sense is generally evaluated using repositioning tests such as active or passive angle reproduction[19]. This study conducted both the measurement of passive angle repositioning (PAR) and active angle repositioning (AAR). In PAR, the subjects' forearms were passively moved to the target angle by the machine, whereas in AAR, the subjects actively moved their forearms to the target angle. PAR and AAR assessments were executed using the method described by Ju et al.[10] For PAR, the forearm was rotated by the machine with the subject's forearm in a starting position between 0° and 80° relative to the target supination angle by random selection. The rotation occurred at a velocity of 2°/s. The forearm was held at the target angle for 5 seconds, and then passively returned to the starting position with a rest period of 10 seconds. The subject then actively reproduced the selected target supination angle which had been passively positioned by the device. The subject pressed a handheld stop button when they felt they had reproduced the correct target supination angle. The set of repositioning tests was performed three times and the subject rested for 20 seconds between each test. In order to avoid any learning effect during the measurements, we chose different angle settings for each test.

Table 1. General characteristics of the subjects

	Total (N=23)
Age (year)	26.52 ± 4.27
Body weight (kg)	58.15 ± 9.67
Height (cm)	163.72 ± 6.80

Values are mean ± SD

For AAR, the subjects actively moved their forearms to the target supination angle, approximately 0~80°, by random selection. All other procedures used were identical to the passive measurement method. The difference between the reproduced angle and the target angle was calculated. The position sense error was evaluated using the absolute error score. All subjects were measured at pre-test prior to intervention, and at post-test after the intervention. All measurements were repeated three times, with a one-minute break between measurements.

All subjects randomly performed both RPM and RAM exercises for two days. At random, one of the interventions was assigned on the first day with the remaining intervention performed on the second day in order to avoid a learning effect.

The RPM exercise was performed with the Biodex using the system's passive exercise module. The device was set to move in a passive supination-pronation mode within a 0° to 80° range with a repetition of 60 times. The angular velocity of the passive exercise module was 120°/s. The RAM exercise was carried out using the Biodex system's isokinetic exercise module with an angular velocity of 120°/s. The subjects were instructed to perform the supination (concentric) and pronation (eccentric) exercises within a range of 0° to 80° for 60 repetitions. Each exercise was performed in three sets, with a one-minute break after each set.

Data was analyzed using SPSS version 18.0 for Windows. The results are presented as the mean and standard deviation. The data collected in this study was analyzed using parametric statistical tests. The analysis used the paired t-test for differences in the position sense error score before and after the intervention. Significance was accepted for values of $p<0.05$.

RESULTS

The position sense error scores at pre- and post-test are shown in Table 2. In the RPM test there was a statistically significant decrease in the AAR error score between pre- and post-test (mean±SD: 6.53±2.89° vs. 4.75±2.13°; $p=0.008$), as well as in the PAR error score (7.65±3.51° vs. 5.84±3.20°; $p=0.039$). In the RAM test, there was a statistically significant increase in the AAR error score in between pre- and post-test (6.53±2.89° vs. 8.05±3.48°; $p=0.041$), as well as in the PAR error score (7.65±3.51° vs. 9.63±3.48°; $p=0.041$).

The comparison of the error scores of the position sense in both the RPM and RAM tests after the movement intervention are shown in Table 3. There was a statistically significant difference in the AAR error scores in RPM,

Table 2. Position sense error score at baseline and after the movement interventions

Measurement	Baseline	RPM	RAM
PAR	7.65 ± 3.51	5.84 ± 3.20*	9.63 ± 3.48*
AAR	6.53 ± 2.89	4.75 ± 2.13**	8.05 ± 3.48*

Values are mean ± SD
Abbreviations: RPM, repetitive passive movement; RAM, repetitive active movement; PAR, passive angle repositioning; AAR, active angle repositioning. *p<0.05, **p<0.01: significant difference between baseline and after the intervention.

Table 3. The comparison of error scores of position sense between RPM and RAM

Measurement	RPM	RAM
PAR	−1.81 ± 3.95	1.98 ± 4.38**
AAR	−1.78 ± 2.92	1.52 ± 3.35**

Values are mean ± SD
Abbreviations: RPM, repetitive passive movement; RAM, repetitive active movement; PAR, passive angle repositioning; AAR, active angle repositioning. **p<0.01: significant difference between RPM and RAM.

−1.78±2.92°, versus RAM, 1.52±3.35°(p=0.001), as well as in the PAR scores in RPM, −1.81±3.95°, versus RAM, 1.98±4.38°(p=0.002).

DISCUSSION

Proprioception plays a role in detecting small changes in the movement of joint location through the sensory receptors in muscle spindles of the joints and muscles[20, 21]. Proprioception enables neuromuscular control of dynamic restraints and segmental movements, and delivers position information to the motor control system[6, 22]. Motor control is an important aspect of rehabilitation[23]. Loss of proprioception capability leads to microtrauma, re-injury of previously damaged joints, deficits in postural control and joint instability[24, 25]. Accordingly, various interventions for improving proprioception have been performed. Fitzgerald[26] reported that closed-chain exercise is more effective at facilitating proprioceptors than open-chain exercise, and therapeutic exercises such as sensorimotor training[27], proprioceptive feedback training[28] and re-education exercise of proprioceptors[29] have been reported to be effective at improving proprioceptor senses.

In this study, we studied passive and active movements. Kisner and Colby[3] explained that passive exercise promotes awareness of movement. Friemert et al.[19] evaluated the effects of a continuous active motion (CAM) device on joint proprioception, and found a significant increase in joint position sense after the CAM exercise.

The goal of our study was to determine which exercise type, RPM or RAM, was more effective for proprioception training.

In the present study, the accuracy of proprioception was measured using a Biodex, and there was a significant difference in both active repositioning and passive repositioning found in RPM, both before and after intervention (p<0.05). Changing the pattern of RPM resulted in a decrease in the error score of position sense.

Friemert et al.[19] found that, after RPM exercise, the proprioception error was reduced. Ju et al.[10] had 15 subjects perform RAM and RPM exercises, and the RAM exercises resulted in an increase in proprioception error scores while RPM resulted in a decrease. This result was the same as the one found in our study, indicating that RPM exercises reduce proprioception errors.

Passive movements play a role in the activation of mechanical receptors and increase activity in the contralateral sensorimotor cortex, supplementary motor area, bilateral inferior parietal cortex, secondary somatosensory areas and ipsilateral cerebellum of the brain[9, 30]. This activation of the brain enables the position of joints to be determined by sensory inputs from the peripheral system, allows the planning of movements, controls the motor response by comparing the sensory input signals and output signals, and provides a significant input to the ability to sense joint position[23]. For all of these reasons, we should expect that repetitive passive movement would function to reduce error in the sensation of position.

In RAM, there was a significant difference observed in both the AAR and PAR, both before and after the intervention (p<0.05). However, the changing patterns of RAM and RPM were different. RAM showed an increasing trend in the error score of position sense.

RAM exercise consisted of concentric and eccentric exercises in our study. Allen et al.[31] reported that forearm concentric and eccentric exercises increased position matching errors and reduced the accuracy of the sense of position[18, 32]. Brockett et al.[15] argued that eccentric exercise increases errors in the sense of position. This result supports the finding of our study that RAM exercise increases error in position sense.

The intensity of brain activation can be influenced by proprioceptive stimulation at the joint[33]. Brain activation occurs in active exercise as well as passive exercise[34]. Active exercise results in fatigue at the joint, whereas passive exercise does not. Continuous high-intensity exercise causes muscle fatigue which increases the error in the position sense by reducing the threshold sensitivity of fibers in the muscle spindles[15, 35, 36]. Therefore, we should expect that continuous active movement would increase errors in the position sense.

A limitation of the present study was that it is difficult to generalize research results using young and healthy persons to the elderly and people whose forearms are injured or impaired. This was not a randomized controlled trial (RCT) and the number of study subjects was small. Therefore, future studies should include more subjects or be conducted as a RCT with participants of different ages and subjects whose forearms are injured or impaired.

We conducted this study in order to examine which of RAM or RPM exercise is more effective for training forearm proprioception. The results of show that RAM exercise increased proprioception errors and RPM reduced them. Thus, RPM exercise is more effective for forearm proprioception training than RAM. Therefore, we recommend the use of RPM exercise in clinical situations in order to improve proprioception ability related to the use of the forearm and stability of joints.

REFERENCES

1) Magee DJ, Zachazewski JE, Quillen WS: Pathology and intervention in musculoskeletal rehabilitation. Elsevier, 2009.
2) Kapandji A: Biomechanics of pronation and supination of the forearm. Hand Clin, 2001, 17: 111–122 vii. [Medline]
3) Kisner C, Colby LA: Therapeutic Exercise Foundations and Techniques. FA Davis, 2002.
4) Dunning CE, Zarzour ZD, Patterson SD, et al.: Muscle forces and pronation stabilize the lateral ligament deficient elbow. Clin Orthop Relat Res, 2001, 118–124. [Medline] [CrossRef]
5) Kavounoudias A, Gilhodes JC, Roll R, et al.: From balance regulation to body orientation: two goals for muscle proprioceptive information processing? Exp Brain Res, 1999, 124: 80–88. [Medline] [CrossRef]
6) Riemann BL, Lephart SM: The sensorimotor system, part II: the role of proprioception in motor control and functional joint stability. J Athl Train, 2002, 37: 80–84. [Medline]
7) Hurley MV, Rees J, Newham DJ: Quadriceps function, proprioceptive acuity and functional performance in healthy young, middle-aged and elderly subjects. Age Ageing, 1998, 27: 55–62. [Medline] [CrossRef]
8) Ju YY, Liu YC, Cheng HY, et al.: Rapid repetitive passive movement improves knee proprioception. Clin Biomech (Bristol, Avon), 2011, 26: 188–193. [Medline] [CrossRef]
9) Baek JH, Kim JW, Kim SY, et al.: Acute effect of repeated passive motion exercise on shoulder position sense in patients with hemiplegia: a pilot study. NeuroRehabilitation, 2009, 25: 101–106. [Medline]
10) Ju YY, Wang CW, Cheng HY: Effects of active fatiguing movement versus passive repetitive movement on knee proprioception. Clin Biomech (Bristol, Avon), 2010, 25: 708–712. [Medline] [CrossRef]
11) Lattanzio PJ, Petrella RJ: Knee proprioception: a review of mechanisms, measurements, and implications of muscular fatigue. Orthopedics, 1998, 21: 463–470. [Medline]
12) Hazneci B, Yildiz Y, Sekir U, et al.: Efficacy of isokinetic exercise on joint position sense and muscle strength in patellofemoral pain syndrome. Am J Phys Med Rehabil, 2005, 84: 521–527. [Medline] [CrossRef]
13) Bartlett MJ, Warren PJ: Effect of warming up on knee proprioception before sporting activity. Br J Sports Med, 2002, 36: 132–134. [Medline] [CrossRef]
14) Chen EW, Fu AS, Chan KM, et al.: The effects of Tai Chi on the balance control of elderly persons with visual impairment: a randomised clinical trial. Age Ageing, 2012, 41: 254–259. [Medline] [CrossRef]
15) Brockett C, Warren N, Gregory JE, et al.: A comparison of the effects of concentric versus eccentric exercise on force and position sense at the human elbow joint. Brain Res, 1997, 771: 251–258. [Medline] [CrossRef]
16) Ribeiro F, Mota J, Oliveira J: Effect of exercise-induced fatigue on position sense of the knee in the elderly. Eur J Appl Physiol, 2007, 99: 379–385. [Medline] [CrossRef]
17) Allen TJ, Leung M, Proske U: The effect of fatigue from exercise on human limb position sense. J Physiol, 2010, 588: 1369–1377. [Medline] [CrossRef]
18) Walsh LD, Allen TJ, Gandevia SC, et al.: Effect of eccentric exercise on position sense at the human forearm in different postures. J Appl Physiol, 2006, 100: 1109–1116. [Medline] [CrossRef]
19) Friemert B, Bach C, Schwarz W, et al.: Benefits of active motion for joint position sense. Knee Surg Sports Traumatol Arthrosc, 2006, 14: 564–570. [Medline] [CrossRef]
20) Hughes T, Rochester P: The effects of proprioceptive exercise and taping on proprioception in subjects with functional ankle instability: a review of the literature. Phys Ther Sport, 2008, 9: 136–147. [Medline] [CrossRef]
21) Blasier RB, Carpenter JE, Huston LJ: Shoulder proprioception. Effect of joint laxity, joint position, and direction of motion. Orthop Rev, 1994, 23: 45–50. [Medline]
22) Hasan Z, Stuart DG: Animal solutions to problems of movement control: the role of proprioceptors. Annu Rev Neurosci, 1988, 11: 199–223. [Medline] [CrossRef]
23) Shumway-Cook A, Woollacott MH: Motor control translating research into clinical practice. Lippincott Williams & Wilkins, 2007.
24) Lephart SM, Pincivero DM, Giraldo JL, et al.: The role of proprioception in the management and rehabilitation of athletic injuries. Am J Sports Med, 1997, 25: 130–137. [Medline] [CrossRef]
25) Kavounoudias A, Roll R, Roll JP: Foot sole and ankle muscle inputs contribute jointly to human erect posture regulation. J Physiol, 2001, 532: 869–878. [Medline] [CrossRef]
26) Fitzgerald GK: Open versus closed kinetic chain exercise: issues in rehabilitation after anterior cruciate ligament reconstructive surgery. Phys Ther, 1997, 77: 1747–1754. [Medline]
27) Tsauo JY, Cheng PF, Yang RS: The effects of sensorimotor training on knee proprioception and function for patients with knee osteoarthritis: a preliminary report. Clin Rehabil, 2008, 22: 448–457. [Medline] [CrossRef]
28) Garland SJ, Miles TS: Control of motor units in human flexor digitorum profundus under different proprioceptive conditions. J Physiol, 1997, 502: 693–701. [Medline] [CrossRef]
29) Vad V, Hong HM, Zazzali M, et al.: Exercise recommendations in athletes with early osteoarthritis of the knee. Sports Med, 2002, 32: 729–739. [Medline] [CrossRef]
30) Ward NS, Brown MM, Thompson AJ, et al.: Longitudinal changes in cerebral response to proprioceptive input in individual patients after stroke: an FMRI study. Neurorehabil Neural Repair, 2006, 20: 398–405. [Medline] [CrossRef]
31) Allen TJ, Ansems GE, Proske U: Effects of muscle conditioning on position sense at the human forearm during loading or fatigue of elbow flexors and the role of the sense of effort. J Physiol, 2007, 580: 423–434. [Medline] [CrossRef]
32) Paschalis V, Nikolaidis MG, Theodorou AA, et al.: Eccentric exercise affects the upper limbs more than the lower limbs in position sense and reaction angle. J Sports Sci, 2010, 28: 33–43. [Medline] [CrossRef]
33) Thijs Y, Vingerhoets G, Pattyn E, et al.: Does bracing influence brain activity during knee movement: an fMRI study. Knee Surg Sports Traumatol Arthrosc, 2010, 18: 1145–1149. [Medline] [CrossRef]
34) Schneider S, Rouffet DM, Billaut F, et al.: Cortical current density oscillations in the motor cortex are correlated with muscular activity during pedaling exercise. Neuroscience, 2013, 228: 309–314. [Medline] [CrossRef]
35) Skinner HB, Wyatt MP, Hodgdon JA, et al.: Effect of fatigue on joint position sense of the knee. J Orthop Res, 1986, 4: 112–118. [Medline] [CrossRef]
36) Marks R: Effect of exercise-induced fatigue on position sense of the knee. Aust J Physiother, 1994, 40: 175–181.