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The Effects of Aging on Visuomotor Coordination and Proprioceptive Function in the Upper Limb

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Abstract. [Purpose] Sensorimotor processing, including motor performance, is altered during the process of normal aging. Previous studies have investigated tasks requiring complex visuomotor coordination and active joint reposition tests. Therefore, the purpose of this study was to investigate age-related changes in upper limb tasks, such as visuomotor coordination and proprioceptive acuity. [Subjects and Methods] We recruited 20 healthy elderly subjects and 20 healthy young subjects. We evaluated a tracking task for visuomotor function and a joint reposition test for integrity of proprioceptive sense in both hands of the elderly subjects, and compared the results with those of the healthy young subjects. [Results] The accuracy index scores for the tracking task were significantly lower in both the dominant and non-dominant hands of the elderly subjects than those of the young group. In addition, the reposition error score in the joint reposition test was significantly higher in the elderly group than in the young group. [Conclusion] Sensorimotor functions of both the dominant and non-dominant hands showed a decline in the elderly group. This finding suggests that sensorimotor function deteriorates with advancing age.

Key words: Aging, Sensorimotor function, Upper limb

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INTRODUCTION

Alteration of sensorimotor processing (as well as motor performance) occurs during the process of normal aging. Numerous studies have demonstrated that this ability deteriorates with advancing age[1, 2)]. Deficits of sensorimotor performance in the elderly include coordination difficulty[3)], increased variability of movement[4, 5)], slowing of movement[6)], and difficulties with balance and gait[7)], in comparison to young adults. These deficits have a negative impact on the ability of older adults to perform functional activities of daily living.

Several recent studies have reported that onset of movement is delayed and trajectory formation is impaired and highly inaccurate in patients with impaired sensorimotor function[8)]. In particular, proprioceptive acuity requires the integrity of all of the sensory systems that contribute to its appreciation: that is, muscle spindles, Golgi tendon organs, articular and cutaneous proprioceptors, the visual field, and vestibular apparatus[9)]. These deficits in sensorimotor performance in older adults appear to be caused by dysfunction of the central and peripheral nervous systems as well as the neuromuscular system[10)].

Many previous studies have investigated age-related declines in sensorimotor function. However, most studies examining changes in sensorimotor function in elderly persons have focused on their ability to either detect passive motion or reproduce passively determined joint positions in the lower limb. Thus, the purpose of this study was to investigate age-related changes in upper limb visuomotor coordination and proprioceptive acuity.

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SUBJECTS AND METHODS

Elderly subjects, who exercised regularly and were in good physical condition (self-reported) were selected for participation in this study. In order to be eligible to participate in the study, elderly subjects were recruited from a local senior sports association and were required to pass a general clinical examination. Findings on their clinical examination did not reveal any musculoskeletal defects or any constraints in the mobility of the upper limbs. Young subjects were recruited from among students at a university. All of these subjects were right-handed, according to the Edinburgh handedness inventory[11)]. To control the known effects of hand asymmetry, the accuracy and proprioceptive tests were performed by subjects using their dominant right hand, and the remaining tasks were performed using their non-dominant left hand. As required by the Helsinki declaration and the local ethics committee, all subjects signed a consent form stating that they had been informed about the nature of the experiment, and that their participation was on a voluntary basis with no remuneration.

Participants performed tracking and joint position sense tests using both their right hand and left hand. All subjects were seated in front of a table, with the forearm comfortably supported and the elbow flexed at 90°. A plastic-frame with an embedded potentiometer was used to measure the accuracy of movement and proprioceptive sense in the metacarpohalangeal (MP) joints. The potentiometer detected flexion/extension motion of the MP joint, and the analog signal was read into a computer with analog-to-digital data acquisition software.

In the tracking task, the subject was instructed to track the target, a red sine wave displayed on a computer screen, as accurately as possible. The response sine wave made by subjects was displayed as a black solid line, which tracked up as the MP joint extended and tracked down as the MP joint flexed. After sufficient explanation, all participants performed one practice, and were measured in three trials, in sequence. At this time, we checked that they had no visual problems with eyesight and visual field. Accuracy of the motor performance was analyzed using an accuracy index (AI), which normalized the range of motion of the MP joint for each individual subject, and calculated the differences between subjects in the excursion of the response wave from the target wave. Prior to the evaluation, three practice trials were provided after one demonstration, using sine waves that were different from the sine wave used in the actual test in order to prevent a learning effect. The joint position sense was evaluated of the MP joint on the right and left sides of all subjects. In addition, the same experimental apparatus and environment as used for the tracking task were used. The subjects were instructed to actively reproduce the position of the MP joint to where it was passively positioned by the examiner. Three different passively-positioned angles were randomly presented, 50%, 70%, and 90% of the flexion angle of the total range of motion of the MP joint. The mean value of three trials in the joint reposition errors between the passively-positioned angles and the actively-positioned angles was calculated. Subjects wore a blindfold in order to eliminate visual feedback.

The χ^2 test was performed to analyze the differences in sex distribution between the young adults and the elderly subjects. The independent t-test was performed to determine the significance of the differences in age, the accuracy of tracking, and the joint position sense. All statistical analyses were performed using PAWS 18.0 (SPSS Inc., Chicago, IL, USA), and $p< 0.05$ was used as the criterion for statistical significance.

RESULTS

The mean age of the 20 elderly subjects (eight men and 12 women) was 65.25±3.37years. The mean age of the 20 young subjects (nine men and 11 women) was 24.60±4.23years. No significant differences in the distribution of sex were observed between the two groups.

The means±SD for the tracking task and joint reposition test of both groups are shown in Table 1. For motor function, the elderly group showed a lower accuracy index in the MP joint than the young adult group. The sensory function measured by the joint reposition test in the elderly group showed higher reposition errors than the young adult group. The results of the statistical analysis indicate that both motor accuracy and sensory function were significantly lower in the elderly group, compared to the young adult group ($p<0.05$).

DISCUSSION

In this study, we attempted to determine whether elderly subjects showed sensorimotor deterioration in the distal part of the upper limb. We evaluated sensorimotor function using a tracking task for visuomotor coordination and a joint reposition test for the proprioceptive sense integrity. Our findings show the elderly subjects had a lower accuracy index in the tracking test, and a higher error score in the joint reposition test, compared to the young adults. Therefore, subjects in the elderly group had greater difficulty with visuomotor coordination and poorer proprioceptive sense integrity than the young subjects.

Advancing age causes a decline in sensorimotor function involving both the central and peripheral levels. At the peripheral level, a myriad of changes occur with age at the level of the individual proprioceptors[12]. Briefly, human and animal studies of aged muscle spindles have revealed: increased capsular thickness[13], decreased spindle diameter[14], decreased sensitivity[15, 16], reduced total numbers of intrafusal fibers[17], and axonal swelling/expanded motor endplates[13], which may be the result of denervation[17]. In addition, cutaneous mechanoreceptors, such as the Meissner and Pacinian type corpuscles, are altered, and show decreased numbers and mean density of receptors per unit of skin area[18, 19]. Also, a decline in the number of joint mechanoreceptors is experienced with age, especially of Ruffini, Pacinian, and Golgi-tendon type receptors[20, 21]. Taken together, these peripheral changes are a potential source of sensorimotor deficits in the elderly.

Table 1. Motor accuracy and reposition accuracy of each group

		Elderly group	Young group
Accuracy index (RMS/V)	Right*	3.49±0.74	7.65±0.71
	Left*	3.00±1.21	7.28±0.67
Reposition error(°)	Right*	5.59±2.54	2.99±1.77
	Left*	6.01±2.5	3.56±1.47

Mean ± SD
*, significantly different, $p<0.05$

At the central level, conductive function of central somatosensory pathways is affected by normal aging[22]. Aging induces progressive loss of the dendrite system in the motor cortex[23], leading to losses in the number of neurons and receptors, as well as neurochemical changes in the brain. Age-related changes in spindle sensitivity can result from supraspinally mediated changes in the gamma drive to the spindles themselves, and changes in the "set" of muscle spindles will have a direct effect on sensitivity[24]. Therefore, these central changes may also contribute to the diminishment of sensorimotor function in elderly individuals. In addition, age-related changes seem to occur in the lens and the pupil accounting for the majority of vision limitations people experience as they get older. These changes would also affect the visuomotor coordination of elderly individuals.

The clinical implication of our findings is that advancing age results in significant deterioration in sensorimotor function. In this study, when interpreting the data, several aspects of advancing age should be taken into account. First, the number of patients included in this study was limited. In addition, the elderly subjects were a heterogeneous group; therefore, care must be taken when drawing generalized conclusions from the data. Second, our study was restricted to a proximal single joint and a specific laboratory task; therefore, we did not establish what impact the sensorimotor deterioration demonstrated by our finding had on the elderly subjects' ability to perform tasks of daily living. Future studies addressing these issues will be required.

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