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

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.

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...
In order to eliminate visual feedback, the setup of the experiment included positioning the angles was calculated. Subjects wore a blindfold during the tracking task to prevent visual cues. In the joint reposition test, subjects were 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 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 calculated. A parametric statistical analysis was performed using a t-test. The results of this analysis revealed that the elderly group had 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).

### RESULTS

The mean age of the 20 elderly subjects (eight men and 12 women) was 65.25±3.37 years. The mean age of the 20 young subjects (nine men and 11 women) was 24.60±4.23 years. 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. Briefly, human and animal studies of aged muscle spindles have revealed: increased capsular thickness, decreased spindle diameter, decreased sensitivity, reduced total numbers of intrafusal fibers, and axonal swelling/expanding motor endplates, which may be the result of denervation. In addition, cutaneous mecanoreceptors, such as the Meissner and Pacinian type corpuscles, are altered, and show decreased numbers and mean density of receptors per unit of skin area. Also, a decline in the number of joint mecanoreceptors is experienced with age, especially of Ruffini, Pacinian, and Golgi-tendon type receptors. 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 |
|---------------------------------------------------------------|
| **Accuracy index (RMS/V)** | Elderly group | Young group |
| Right* | 3.49±0.74 | 7.65±0.71 |
| Left* | 3.00±1.21 | 7.28±0.67 |
| **Reposition error(*)** | Elderly group | Young group |
| 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. Aging induces progressive loss of the dendrite system in the motor cortex, 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 supra- and pinally 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. 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 participants 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.

REFERENCES

1) McNay EC, Willingham DB: Deficit in learning of a motor skill requiring strategy, but not of perceptuomotor recalibration, with aging. Learn Mem, 1998, 4: 411–420. [Medline] [CrossRef]
2) Pratt J, Chasteen AL, Abrams RA: Rapid aimed limb movements: age differences and practice effects in component submovements. Psychol Aging, 1994, 9: 325–334. [Medline] [CrossRef]
3) Seidler RD, Alberts JL, Stelmach GE: Changes in multi-joint performance with age. Motor Control, 2002, 6: 19–31. [Medline]
4) Contreras-Vidal JL, Teulings HL, Stelmach GE: Elderly subjects are impaired in spatial coordination in fine motor control. Acta Psychol (Amst), 1998, 100: 25–35. [Medline] [CrossRef]
5) Darling WG, Cooke JD, Brown SH: Control of simple arm movements in elderly humans. Neurobiol Aging, 1989, 10: 149–157. [Medline] [CrossRef]
6) Madden DJ, Pierce TW, Allen PA: Age-related slowing and the time course of semantic priming in visual word identification. Psychol Aging, 1993, 8: 490–507. [Medline] [CrossRef]
7) Lord SR, Ward JA: Age-associated differences in sensori-motor function and balance in community dwelling women. Age Ageing, 1994, 23: 452–460. [Medline] [CrossRef]
8) Ghuz C, Gordon J, Gihlardi MF: Impairments of reaching movements in patients without proprioception. II. Effects of visual information on accuracy. J Neurophysiol, 1995, 73: 361–372. [Medline]
9) Fitzpatrick R, McCloskey DI: Changes within human biceps brachii. J Physiol, 1994, 478: 173–186. [Medline]
10) Seidler RD, Bernard JA, Burutolu TB, et al.: Motor control and aging: links to age-related brain structural, functional, and biochemical effects. Neurosci Biobehav Rev, 2010, 34: 721–733. [Medline] [CrossRef]
11) Oldfield RC: The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia, 1971, 9: 97–113. [Medline] [CrossRef]
12) Shaffer SW, Harrison AL: Aging of the somatosensory system: a transnational perspective. Phys Ther, 2007, 87: 193–207. [Medline] [CrossRef]
13) Swash M, Fox KP: The effect of age on human skeletal muscle. Studies of the morphology and innervation of muscle spindles. J Neurol Sci, 1972, 16: 417–432. [Medline] [CrossRef]
14) Karatzou E, Manta P, Kalfakis N, et al.: Morphometric study of the human muscle spindle. Analytical and quantitative cytology and histology / the International Academy of Cytology. Am Soc Cytol, 2005, 27: 1–4.
15) Burke JR, Schutten MC, Koecke DM, et al.: Age-dependent effects of muscle vibration and the Jendrassik maneuver on the patellar tendon reflex response. Arch Phys Med Rehabil, 1996, 77: 600–604. [Medline] [CrossRef]
16) Kim GH, Suzuki S, Kanda K: Age-related physiological and morphological changes of muscle spindles in rats. J Physiol, 1997, 528: 525–538. [Medline] [CrossRef]
17) Liu JX, Eriksson PO, Thornell LE, et al.: Fiber content and myosin heavy chain composition of muscle spindles in aged human biceps brachii. J Histochem Cytochem, 2005, 53: 445–454. [Medline] [CrossRef]
18) Bruce MF: The relation of tactile thresholds to histology in the fingers of elderly people. J Neurol Neurosurg Psychiatry, 1980, 43: 730–734. [Medline] [CrossRef]
19) Iwasaki T, Goto N, Goto J, et al.: The aging of human Meissner’s corpuscles as evidenced by parallel sectioning. Okajimas Folia Anat Jpn, 2003, 79: 185–189. [Medline] [CrossRef]
20) Aydoğ˘ ST, Korkusuz P, Doral MN, et al.: Decrease in the numbers of mechanoreceptors in rabbit ACL: the effects of ageing. Knee Surg Sports Traumatol Arthrosc, 2006, 14: 325–329. [Medline] [CrossRef]
21) Morisawa Y: Morphological study of mechanoreceptors on the coracocromial ligament. J Orthop Sci, 1998, 3: 102–110. [Medline] [CrossRef]
22) Tanosaki M, Ozaki I, Shimamura H, et al.: Effects of aging on central conduction in somatosensory evoked potentials: evaluation of onset versus peak methods. Clin Neurophysiol, 1999, 110: 2094–2103. [Medline] [CrossRef]
23) Nakamura S, Akiyama K, Kameyama M, et al.: Age-related changes of pyramidal cell basal dendrites in layers III and V of human motor cortex: a quantitative Golgi study. Acta Neuropathol, 1985, 65: 281–284. [Medline] [CrossRef]
24) Strong R: Neurochemical changes in the aging human brain: implications for behavioral impairment and neurodegenerative disease. Geriatrics, 1998, 53: S9–S12. [Medline]