



Original Article

Three-dimensional motion analysis in the elbow joint position sense in children

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Abstract. [Purpose] The purpose of this study was to investigate the difference in elbow joint position sense in children. [Subjects and Methods] Nineteen healthy children volunteered as subjects for this study. Joint position sense was assessed by asking the children to flex their elbows between 30° to 110° while blindfolded. The error range of elbow movement was analyzed with Compact Measuring System 10 for three-dimensional motion. To analyze data, descriptive statistics and paired t-test analysis were performed by using IBM SPSS Statistics 20.0. [Results] A significantly lower error was found in 30° right elbow flexion than 110° right elbow flexion ($p < 0.05$). No significant difference was found between 30° and 110° left elbow flexion. [Conclusion] These results indicate that in children, joint position sense errors decrease as joint angles approach 30° flexion.

Key words: Children, Elbow, Joint position sense

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INTRODUCTION

Joint position sense (JPS) is defined as the ability to maintain a static limb position. This is a somatosensory function that provides inputs from muscles and joints without the assistance of vision¹). JPS is an individual's ability to reproduce a previous determined position and a parameter of proprioception. In children with difficulties related to proprioception, performance of activities that involve movements in space may be affected. This is associated with the integration of proprioception with other sensory information for the planning and control of movement²). This ability is of great important for children in, for example, play. Poor elbow JPS reduces motor performance of hand-arm coordination³). Proper orientation of the upper extremity is necessary for accurate and precise hand positioning. High proprioceptive acuity in the upper extremity is necessary for accurate positioning of the hand in space. Poor JPS has been reported as a factor related to motor coordination in children with development coordination disorder⁴).

JPS is measured accurately based on joint angle replication in an open or closed chain environment. Many types of assessment methods for JPS are used, such as simple goniometers or isokinetic dynamometers, and electromagnetic tracking devices⁵). To investigate elbow JPS, we used a three-dimensional (3-D) motion analyzer. In measuring JPS, the most commonly used variable is the absolute difference in degrees between the achieved and target positions. This method is a measure of the precision of the repositioning error⁶).

Although the authors of several studies have claimed that they used standardized reproducible methods for measuring JPS of the elbow, to our knowledge, no study has been published on elbow JPS in children. The aim of this study was to investigate the difference in target angle error of elbow JPS in children (target angles, 30° and 110°).

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SUBJECTS AND METHODS

Nineteen healthy children (15 boys and 4 girls) with a mean age of 9.7 ± 0.36 years participated in this study. All the subjects were right-handed. The children had no evidence of functional motor problems. Prior to the study, the children and their parents were informed of the purpose of this study and the general procedures to be undertaken. All the children and parents signed an informed consent form. The study was approved by the Human Health Science Studies Committee of Kaya University.

To measure elbow JPS, the children were blindfolded to block visual information and instructed to move at a consistent speed according to a metronome. Calibration was performed with the subjects sitting on a chair, with both hands in a neutral position. We measured 30° and 110° elbow flexion by using a goniometer and showed them the angles by moving their elbows passively. After a 5-minute break, the children were directed to repeat 30° and 110° elbow flexion in time with a metronome set at 1-second intervals. The children were then directed to repeat this motion 10 times in time with a metronome set at 1-second intervals. The right elbow was measured first, and the left was measured immediately after. Each subject was instructed to relax during the testing and was told to press the response button when they thought that the limb had reached the target position previously demonstrated.

Their movements were recorded by using the Compact Measuring System (CMS) 10 for 3-D motion analysis (WinArm software, Zebris Medical GmbH, Germany). CMS markers were placed at the greater tubercle and lateral epicondyle of the humerus and wrist. Angles of deviation from the targeted range of flexion were analyzed by using the MATLAB version 2014a (The MathWorks Inc., Natick, MA, USA).

To compare the difference in JPS error at 30° and 110° flexion, a paired t-test was used. All data were analyzed by using the IBM SPSS Statistics for Windows software package (ver. 20.0, IBM Corp., Armonk, NY, USA). A p value of <0.05 was considered to indicate statistical significance.

RESULTS

Table 1 presents the mean and SD of the angular error. The lowest error was observed for 30° right elbow flexion, while the highest error was observed for 110° left elbow flexion. We examined whether JPS differs in accordance with the angle and found a significantly lower error for 30° right elbow flexion than 110° right elbow flexion ($p<0.05$). No significant difference was found between 30° and 110° left elbow flexion.

DISCUSSION

Elbow joint movement is necessary during activities such as performing fine manipulative tasks, and JPS is generally known to be part of the neuromuscular afferent detection system⁷. The purpose of this study was to provide better understanding of active joint position sense ability for the elbow in children. We examined whether the error in JPS differs in accordance with changes in angles and found a smaller error for 30° flexion than for 110° flexion in the right elbow. Although statistically insignificant, the error for 30° flexion was smaller than that for 110° flexion in the left elbow. The more often JPS is used in daily life, the more likely it is stored as body schema in the sensory and motor systems of the brain⁸. Movement at 30° elbow flexion is repeatedly used in daily lives, as it stabilizes eating or writing motions. The findings of the present study may have been influenced by such repetitive body movements. Although we had predicted that the dominant hand would have a proprioceptive advantage over the nondominant hand, we found no significant differences in errors between the dominant and nondominant sides. This is consistent with the findings of previous studies of the upper extremity.

JPS, which is a component of the proprioceptive sense, plays a role in controlling speed and power when performing activities and a critical role in correcting the errors of movement internally or externally⁹. As it is the basis on which humans learn and correct motor skill, it is essential for functional motion in daily lives. Lack of JPS in children is deeply associated with sensory perception problems. When children lack JPS, which relays information to the brain regarding body positions with regard to muscles and joints, their motor abilities are reduced, and they are easily distracted¹⁰. Such children are more inclined to depend on visual information when performing simple tasks such as sitting on a chair or using a fork correctly. People with little information about their body position exert too much or too little force when performing tasks. Furthermore, lack of JPS leads to increased demand for energy when performing activities that require postural maintenance.

Table 1. Comparison of errors according to angle (unit: degree)

	30° flexion	110° flexion
Right	14.2 ± 10.0	22.1 ± 10.8*
Left	16.1 ± 11.3	22.4 ± 9.7

* $p<0.05$

Despite the importance of JPS, however, JPS in children has virtually been neglected in the literature. Hence, we expect the findings of this study to be useful for the treatment of children with impaired JPS.

This study has some limitations. First, the small sample size is insufficient to represent the population. We examined children within a limited age range of 9 to 10 years. Second, the proportion of boys was higher (15 boys and 4 girls). Future studies should examine gender-specific differences.

Most recent studies on JPS have measured JPS in active movement. In active movement, the level of peripheral afferent information generated and received is higher¹¹). In addition, detection of active motion is more comparable with situations in daily life than detection of passive movements. Therefore, future studies should examine the changes in JPS when performing tasks in real-life situations rather than in passive movements.

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