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Original Article

The effect of visual field condition on kinetic in upper extremities and e.m.g in lower extremities while performing reaching in normal adults

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Abstract. [Purpose] The aims of this study was to investigate mean velocity and angle of shoulder joint, activation of tibialis anterior and gastrocnemius according to both eyes, dominant eye and non-dominant eye condition during reaching task in normal adults. [Subjects and Methods] Our research recruited 24 participants (male 11, female 13) in Silla University. Participants were performed reaching out movement by conditions of both eye, dominants eye, non-dominants eye. The target was placed at 45 degree diagonal direction and distance far away 130% of their arm length. Kinetic analysis of the upper extremities was investigated by QUALISYS 3-dimensional motion analysis system. Muscle activation were measured by EMG during reaching tasks. The collected data were statistically processed using the SPSS for win version 20.0. [Results] There was a significant difference of shoulder joint velocity of flexion, abduction and internal rotation according to visual field condition during reaching tasks. There was no significant difference of shoulder joint angle and muscle activation according to visual field conditions during reaching tasks. [Conclusion] In conclusion, visual field has an influence on shoulder joint velocity. Therefore, the visual field may be to play an important role in reach performance.

Key words: Visual field, Kinetic analysis, Reaching

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INTRODUCTION

Motion refers to the ability of performing a given task in a voluntary and goal-oriented manner and is expressed by a complicated interaction between the central nervous system and the musculoskeletal system[1)]. Motion includes the movement of the upper and lower limbs such as throwing, reaching, and walking, and is adjusted by tasks and developed as skillful one through feedback and feed-forward processe[2, 3)].

The motion of reaching, such as picking up an object or reaching the hand toward a target in the environment, is a very essential motion in humans or primates[4)]. Reaching may be adapted through the integration or coordination of senses such as visual sense or proprioceptive sense[5)]. Reaching is the ability of moving the arm and the hand to a target in a space on a positional base of support and is a basic function for daily motion, and it is controlled by the collaboration of learning and proprioceptive sense depending on the size or direction of the target object[6)].

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Balance refers to the ability to control the center of mass with reference to the surface of support and is fundamental for all motions in daily living[7)]. Maintaining balance requires the actions of various sensory organs including visual sense and the vestibular system[8)]. In addition, the balancing ability on the ground is associated with the muscular activity of the tibialis anterior muscle and the gastrocnemius muscle that are related with the ankle joint strategy[9)].

Visual sense provides information of the surrounding environment to maintain balance by leading a goal-oriented motion in coordination with the upper limbs and greatly affect the posture control[10, 11)]. In visual sense, the dominant eye and the non-dominant eye sense and process different information in different durations, and the role of the dominant eye is important in the motion requiring the coordination between hands and eyes depending on the dominant hand[12)].

Therefore, a polyarticular motion such as reaching may easily be damaged if the central nervous system, including pathways related with sensomobility, has a problem[13)]. Understanding the motion of reaching, which is associated with environmental factors, is important in damage prevention and rehabilitation[14)].

Studies have been steadily conducted on the response time and accuracy of the interaction between visual field and upper limbs, which may be easily damaged when the central nervous system has a problem[15)]. The maintenance of balance depending on visual field and the variation of lower limb muscular activity in posture control have been continuously studied. However, the dynamic motion depending on the visual field variation of the dominant and the non-dominant eyes has not been sufficiently studied by a simultaneous analysis of the kinetics of the upper limbs and the muscular activity of the lower limbs.

In the present study, the variation of shoulder joint angle and the variation of the speed of hand segment were compared in the motion reaching depending on the visual field of the dominant eye and the non-dominant eye. Also, the difference in the muscular activity of the tibialis anterior muscle and the gastrocnemius muscle of the lower limbs was investigated.

Therefore, the purpose of the present study was to provide fundamental data for the rehabilitation therapy for patients with stroke by presenting the normal kinetic motion of the upper limb and the lower limb muscular activity in performing the motion of reaching.

SUBJECTS AND METHODS

The subjects of the present study were 24 students of S University in Busan (11 males and 13 females) who were given sufficient explanation about the present study and voluntarily agreed to the participation in the present study. The questionnaire survey based on the Edinburgh Handedness Inventory showed that all the subjects were right-handed[16)]. The hole-in-the-card test method showed that the dominant eye was the right eye in 19 subjects and the left eye in 5 subjects. The subjects were adults in their 20's who had not undergone an ophthalmologic treatment within past six months, who were not physically limited for reaching and who were absent of hypotension or drug administration.

The present study was approved by Silla University Institutional Review Board and the objective of the study and its requirements were explained to the subjects, and all participants provided written parental consent; thus, the rights of human subjects were protected.

Electromyography was performed by using KEYPOINT® of Medtronic. The electrodes were the catheters for surface electromyography. The sampling rate of electromyography signals was 24 KHz and the frequency bandwidth was 1,000 Hz.

To minimize the skin resistance to the surface electromyography signals used in the present study, the body hairs were removed and washed with alcohol swab for medical purposes before arranging the electrodes. The electrodes were attached to the tibialis anterior muscle and the inner gastrocnemius muscle in parallel with the muskelbauch which is the most activated part when the two muscles are contracted to the maximum. While the subjects were performing the motion of reaching with the electrodes attached, the muscular activity was measured by using the Root Mean Square (RMS) values. The motion was repeated five times during five seconds of measurement duration, and the mean values were used for the analysis.

The kinematic change of shoulder joints during reaching motion was analyzed by using the Qualisys system that is three-dimensional motion analysis equipment. This equipment consists of basic instruments such as personal computers, indicators, cameras, and cable adapters. The indicators attached to the upper limbs of the subjects were recognized by cameras and the positional information of the indicators was saved in the computer. The positional information of individual indicators was collected by using the Qualisys track manager software for Windows, and a total of 39 indicators were used. The sampling rate was 60 Hz. The collected data were used to analyze the shoulder joint angle, the average speed of hand segments, and the time required to reach from the starting point to the end point through the visual 3D software program for three-dimensional motion analysis.

The dominant eye was verified by using the hole-in-the-card test, which is a currently used, well-known test method.

A hole of 2.5 cm diameter was made at the center of paper of A4 size (210 × 297 mm). The subjects were instructed to hold the card with both hands and look at an object 6.3 m in front through the hole. The dominant eye was determined by covering each eye one by one.

In the present experiment of performing the motion of reaching with different visual fields, the normal healthy adult subjects were given sufficient explanation about the experimental procedures and voluntarily gave consents about the participation. The general characteristics were firstly investigated, and the dominant eye and dominant hand tests were performed. The order of reaching motion and visual field blockage was randomly determined.

The subjects in the starting posture started to perform reaching at a visual sign in each direction. An eye patch for blocking visual field was used to perform the motion of reaching under different conditions: with both eyes open, with the dominant eye open, and with the non-dominant eye open.

The subjects were asked to perform the motion of reaching comfortably at a natural speed, keeping the opposite hand that was not used for reaching naturally at the starting position. In the starting posture, the shoulder joint angle, the ankle joint angle, and the wrist joint angle were all 0°. To prevent the displacement and rotation of the body trunk while performing the reaching motion, the subjects were given sufficient education and training. Markers were attached at the starting point and the end point of reaching. The experimental task was to perform the motion of reaching toward a target object placed at a position in a distance of 130% of the arm length in the direction of 45° outward at the height of acromioclavicular joint from the ground.

The anatomical posture was set to be the starting position. When a start signal was given to a left or right side in the front, the subjects reached their arm to the marker of the target object. The starting point was set to be the time when a left or right signal was given, and the end point was set to be the time when the hand reached the sticker. The measurement was repeated five times to the left and to the right in all the subjects. The subjects were unaware of the purpose of the experiment.

The subjects were asked to look at a pillar on the left with their both eyes open, and the measurement was performed when the left arm was reached. The measurement was also performed when the right arm was reached while the subjects were looking a pillar on the right. The motion of reaching was performed to the left and to the right while the non-dominant eye was blocked with the eye patch and the dominant eye was open. The motion of reaching was performed to the left and to the right while the dominant eye was blocked with the eye patch and the non-dominant eye was open.

The angle of shoulder joint, the average speed of hand segment, and the muscular activity of the lower limbs while performing the reaching motion were investigated by varying the visual field. The average values were obtained when the subjects performed reaching of their arms to the left or to the right with both eyes open, with the dominant eye open, or with the non-dominant eye open.

One-way ANOVA (analysis of variance) was performed to analyze the angle of shoulder joint, the average speed of hand segment, and the muscular activity of the lower limbs depending on the visual fields. A post-hoc test was performed by a least significant difference (LSD) test. The significance level to test the statistical significant was $\alpha=0.05$. The collected data were analyzed by using the commercially available statistical software SPSS version 18.0 for Windows.

RESULTS

In the three-dimensional motion analysis, the x-axis value from flexion to extension, the y-axis value from adduction to abduction, and the z-axis value of the shoulder joint rotation were taken.

The value from flexion to extension was 92.75 ± 7.21 with both eyes open, 92.71 ± 7.37 with the dominant eye open, and 92.42 ± 8.28 with the non-dominant eye open. The value from adduction to abduction was 43.73 ± 6.28 with both eyes open, 41.93 ± 6.60 with the dominant eye open, 42.26 ± 6.65 with the non-dominant eye open. The shoulder joint rotation value was 31.54 ± 14.87 with both eyes open, 31.73 ± 15.24 with the dominant eye open, and 32.12 ± 14.89 with the non-dominant eye open. No significant difference was found in any of the x-axis, y-axis, and z-axis values (Table 1).

The speed of reaching from the starting point to the end point was measured in the x-axis, y-axis, and z-axis. Significant difference was found in all the axes ($p<0.05$).

The value from flexion to extension was 0.26 ± 0.07 with both eyes open, 0.23 ± 0.07 with the dominant eye open, and 0.22 ± 0.06 with the non-dominant eye open. The value from adduction to abduction was 0.30 ± 0.06 with both eyes open, 0.26 ± 0.07 with the dominant eye open, 0.26 ± 0.06 with the non-dominant eye open. The shoulder joint rotation value was

Table 1. Analysis of joint angle, velocity, muscle activation according each visual field condition

		Visual field condition		
		Both eye	Non dominant eye	Dominant eye
Joint angle (degrees)	X-axis	90.8 ± 7.2	92.4 ± 8.3	92.7 ± 7.4
	Y-axis	43.7 ± 6.3	42.3 ± 6.7	41.9 ± 6.6
	Z-axis	31.5 ± 14.9	32.1 ± 14. 9	31.7 ± 15.2
Joint velocity (m/sec)	X-axis	0.3 ± 0.1[a]	0.2 ± 0.1[b]	0.2 ± 0.1[b]
	Y-axis	0.3 ± 0.1[a]	0.3 ± 0.1[b]	0.3 ± 0.1[b]
	Z-axis	0.4 ± 0.1[a]	0.3 ± 0.1[b]	0.3 ± 0.1[b]
Muscle activation (%)	Lt.TA	14.4 ± 14.442	15.3 ± 16.9	15.0 ± 14.7
	Lt.GCM	42.1 ± 50.2	45.3 ± 52.1	43.3 ± 49.7
	Rt.TA	12.3 ± 11.4	12.9 ± 14.6	12.4 ± 12.8
	Rt.GCM	36.3 ± 40.1	39.5 ± 42.5	39.3 ± 41.8

a, b means post hoc test by LSD

0.37 ± 0.08 with both eyes open, 0.33 ± 0.08 with the dominant eye open, and 0.32 ± 0.07 with the non-dominant eye open. The post hoc test showed that the speed was the highest when both eyes were open, and the values were not significantly different between the condition of open dominant eye and the condition of open non-dominant eye (Table 1).

With regard to the lower limbs muscular activity while performing the motion of reaching depending on the visual fields, no significant difference was found in both the tibialis anterior muscle and the gastrocnemius muscle.

The activity of the left tibialis anterior muscle was 14.37 ± 14.43 with both eyes open, 15.01 ± 14.67 with the dominant eye open, and 15.31 ± 16.93 with the non-dominant eye open. The activity of the right tibialis anterior muscle was 12.28 ± 11.38 with both eyes open, 12.40 ± 12.76 with the dominant eye open, and 12.87 ± 14.62 with the non-dominant eye open.

The activity of the left gastrocnemius muscle was 42.06 ± 50.18 with both eyes open, 43.27 ± 49.70 with the dominant eye open, and 45.27 ± 52.11 with the non-dominant eye open. The activity of the right gastrocnemius muscle was 36.30 ± 40.09 with both eyes open, 39.31 ± 41.77 with the dominant eye open, and 39.48 ± 42.47 with the non-dominant eye open (Table 1).

DISCUSSION

In the present study, the kinematic change of the upper limbs and the muscular activity of the lower limbs were compared in 24 normal adult subjects depending on the visual fields with both eyes open, with the dominant eye open, and with the non-dominant eye open. The experiment was performed by asking the subjects to reach by stretching their arm a bar placed at a position in a distance of 130% of the arm length in the direction of 45° outward to the left or to the right while the subjects were in the standing position.

Aubert et al. analyzed the plantar pressure under the left and right feet by using a three-dimensional motion analyzer and a plantar pressure meter by asking 31 healthy adult subjects to pick up one object out of red and green objects mixed together in an unclear visual field (accuracy 1/10), and reported that the reaching motion was slower in the unclear visual field than in the clear visual field, which was partially consistent with the result of the present study[17)].

Kirgolson and Heath studied the accuracy of reaching motion under visual background condition and without visual background condition, and reported that the accuracy of reaching motion was higher under the visual background condition[18)]. This result indicates that visual guide is more accurate than memory guide, emphasizing the importance of visual state.

Reaching is not properly performed by infants at an age of six months or under because they have insufficient recognition of the visual sense and the hand position, but reaching may be performed even when the visual sense and the hand position are separated as children grow older[19)].

The visual sense may make reaching motion more accurate in adults. A study conducted about the variation of the lower limb muscular activity in the motion of reaching in the standing position showed that the elderly are more affected by visual field conditions than the younger[9)].

A study conducted on the activity of the gastrocnemius muscle and the tibialis anterior muscle while reaching is performed by the elderly at the age of 60 or higher showed that the muscular activity was higher in the gastrocnemius muscle than in the tibialis anterior muscle. On the contrary, the activity was not found to be significantly different between the two muscles in the present study conducted with the adult subjects in their 20's.

Park et al.[20)] reported that the muscular activity of the gastrocnemius muscle was increased for balancing in the motion of reaching and that the lower limb muscular activity was increased when the non-dominant eye was open[22)]. However, no significant difference was found in the present study because the results were similar between the conditions.

The result of the present study was partially consistent with the report that kinematic changes were found depending on the blockage and opening of the visual field in the motion of reaching[21)] and the report that the positional control was not greatly dependent on the opening of the dominant eye or the non-dominant eye in young adults[22)].

The present study is limited because the compensatory motion of the body trunk was not analyzed. The result of the present study may not be generalized with all subjects because the subjects of the present study were limited to normal adults.

In the present study, the variation of shoulder joint angle, the variation of the speed of hand segment, and the muscular activity of the tibialis anterior muscle and the gastrocnemius muscle were investigated in 24 normal subjects while the subjects were performing the motion of reaching in different directions depending on the visual fields.

The results of the present study may be applied in the future to the training of reaching motion for stoke patients who may have both visual damage and motor damage. Further studies may need to be conducted on other variables such as the color, size, and distance of target objects in the motion of reaching.

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