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Original Article

Influence of time restriction, 20 minutes and 94.6 months, of visual information on angular displacement during the sit-to-stand (STS) task in three planes

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Abstract. [Purpose] The purpose of this investigation was to assess whether or not restriction of visual information influences the kinematics of sit-to-stand (STS) performance in children. [Subjects and Methods] Five girls with congenital blindness (CB) and ten healthy girls with no visual impairments were randomly selected. The girls with congenital blindness were placed in one group and the ten girls with no visual impairments were divided into two groups of five, control and treatment groups. The participants in the treatment group were asked to close their eyes (EC) for 20 minutes before the STS test, whereas those in the control group kept their eyes open (EO). The performance of the participants in all three groups was measured using a motion capture system and two force plates. [Results] The results show that the constraint duration of visual sensory information affected the range of motion (ROM), the excursion of the dominant side ankle, and the ROM of the dominant side knee in the EC group. However, only ankle excursion on the non-dominant side was affected in the CB group, and this was only observed in the sagittal plane. [Conclusion] These results indicate that visual memory does not affect the joint angles in the frontal and transverse planes. Moreover, all of the participants could perform the STS transition without falling, indicating; the participants performed the STS maneuver correctly in all planes except the sagittal one.
Key words: Sit-to-stand, Children, Visual memory

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INTRODUCTION

According to a report published by WHO in 2010, 19 million children (1–14 years of age) suffering from vision impairments. Among the 19 million sufferers, 1.4 million were irreversibly blind and needed visual rehabilitation interventions for full psychological and personal development[1)]. Congenitally blind children usually suffer from falls that result in injury[2)] and contusions. The sit-to-stand (STS) movement is one of the safest tasks for blind children to perform. Routinely, the STS movement is performed 60 times on a daily basis by a healthy adult. The STS motion is a substantial determinant of functional fitness[3)], independent mobility[4)], most mechanically demanding tasks[5)], and a prerequisite for gait[6)]. STS requires coordination among all the body segments[5)], and balance[7)]. The central nervous system (CNS) integrates visual sensory information to create an internal representation of the body in the brain. During the STS maneuver, the postural balance control system must be continually updated to prevent falling. Therefore, it could be said that visual feedback is one of the

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most important factors contributing to balance control[8].

Dark adaptation of the visual system is the process of adjusting to total darkness or to lower levels of illumination[9]. The time of the rod intercept is reported to be less than or equal to 20 min, usually 8.2 min[10] and 12.5 min[11], in young and elderly people, respectively. Therefore, in this study, the time the eyes were kept closed was chosen as 20 minutes to ensure occurrence of rod intercept.

The study of visual adaptation is important for a variety of practical reasons as well as for obtaining an understanding of the effects of visual information on the performance of motor tasks. The specific objective of the present study was to characterize the kinematics of STS performance in short- and long-duration dark adaptation tasks. This study aimed to find out how the joints of the lower limb respond (start, maximum, minimum, end, range and excursion points) to long-term constraint of visual data (i.e. congenital blindness), and which planes it affects, as the results would be useful in the design of rehabilitation programs for blind children by identifying the joints involved.

SUBJECTS AND METHODS

The participants in this study were 15 girls who were randomly selected. Five of the girls suffered from congenital blindness (CB). They had a mean (± standard deviation) age of 94.6 (± 5.58) mo, body weight of 25.74 (± 2.12) kg, height of 126.82 (± 0.05) cm, leg length of 36.62 (± 1.58) cm, and anterior superior iliac spines (ASIS) width of 17.76 (± 1.23) cm. The remaining ten girls were healthy and did not have any visual impairment. These ten healthy girls were divided into two groups. The subjects in the treatment group closed their eyes (EC) for 20 minutes before the STS test. They had an age of 93.8 (± 5.88) mo, body weight of 24.16 (± 1.36) kg, height of 124.24 (± 0.044) cm, leg length of 34.56 (± 1.13) cm, and ASIS width of 15.84 (± 0.64) cm. The control group kept their eyes opens (EO). They had an age of 95.8 (± 5.53) mo, body weight of 26.06 (± 5.21) kg, height of 126.66 (± 0.05) cm, leg length of 36.16 (± 1.56) cm, and ASIS width of 16.46 (± 0.95) cm. During the practice and trial phases, the subjects in the EC group kept their eyes closed to prevent any learning taking place through receipt of visual information. The healthy girls had no musculoskeletal or neuromuscular problems and were considered normally active. The blind girls were physically active in daily life and merely suffered from blindness. Informed oral consent was obtained from each subject and their parents after they had been provided with detailed information about the study.

Retro-reflective markers were placed over bony landmarks including the vertex, seventh cervical vertebra (C7), spinous process of the twelfth thoracic vertebrae, and bilaterally on the lateral borders of the acromion process, heads of the humerus, olecranon processes of the ulna, heads of the styloid process of the ulna, ASIS, posterior superior iliac spines (PSIS), greater trochanter, lateral femoral epicondyles, lateral malleoli, 5th distal metatarsal heads, and calcaneal tuberosity.

Before performing the test, the equipment and the instruments were demonstrated with an oral explanation to the participants in the EO group, and through sense of touch for the EC and CB groups. The subjects sat barefoot on a firm chair with no armrest, back support or wheels. The height of the chair was adjusted to 100% of each subject's leg length, the distance from the lateral femoral condyle to the ground. During the STS test, the participants placed one foot on each force plate for 3 to 4 s[12], their arms were folded across the chest, and they wore tight shorts. The subjects sat with their bodies and extremities (thighs, legs and feet) symmetrically placed relative to the chair, and the distance between the feet was determined as the ASIS width. The subjects in EO group were told to place their feet within the outer limits of the two force plates, one foot on each plate. In addition, the subjects were requested to use a self-selected movement strategy. The widths of the ASIS of the EC and CB groups were determined using a thick stick on the force plates. The subjects were instructed to raise their entire body from the chair at a self-selected velocity, and to keep standing when reaching the upright position for 3 to 4 s[12]. Each subject was requested to perform five STS trials with 30-second rests between the trials, and had three practices before the actual test. Lower limb dominance was determined as the foot used to kick a ball[13].

Two adjustable force plates (9260AA6, Kistler, Switzerland) with a sampling frequency of 1,000 Hz, were used to record the ground reaction forces during the performance of the STS task. An eight camera video-based opto-electronic system (Qualisys AB, Sweden, sampling, 100 Hz) was used for 3D motion capture. The force plates and the motion data were filtered using a fourth order Butterworth filter (cutoff frequency of 10 Hz)[14].

The task of STS was defined by three events: (1) the beginning of the movement when the border of the acromion process (shoulder) marker began to move forward in the sagittal plane, (2) the seat-off event when the initiation of knee flexion began, and (3) the end of the STS task was defined as the maximum height of the shoulder marker. According to these events, there were two phases, the preparation phase and the standing phase.

Upper extremity markers were used to define STS events. Markers on the olecranon processes of the ulna and heads of the styloid process of the ulna were used to monitor the arms folded across the chest, because all of the participants were children in this investigation. Markers on the ASIS, PSIS and greater trochanter were used to define the hip joint center. The segments of trunk, thigh, leg and foot were defined as the head of humerus to the hip center, the hip center to the lateral femoral epicondyle, the lateral femoral epicondyle to the lateral malleoli, and the lateral malleoli to the 5th distal metatarsal heads, respectively. Flexion, abduction, and internal rotation occurred at the initiation of movement, and when STS entered its final stages, extension, adduction, and external rotation occurred in the sagittal, frontal, and transverse planes, respectively (Fig. 1).

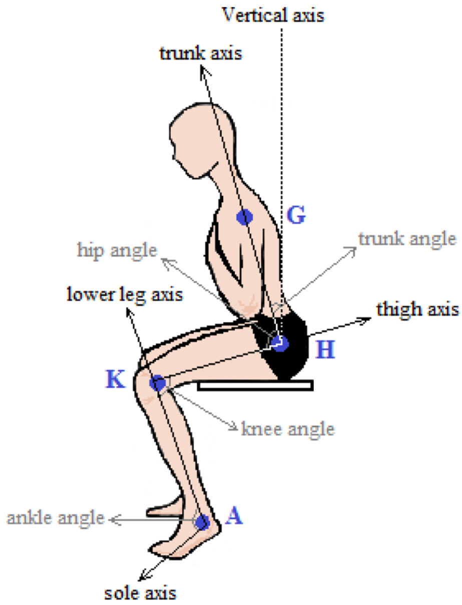

Fig. 1. Joint angle definitions in the sagittal plane
Ankle angle: ankle between the sole axis and lower leg axis. Knee angle: angle between the lower leg axis and the thigh axis. Hip angle: angle between thigh axis and trunk axis. Trunk axis: angle between trunk axis and vertical axis
A: ankle, K: knee, H: hip, G: glenohumeral joint; head of humerus marker

Table 1. Phase durations of sit-to-stand (STS) motion

	Congenital blindness		Eyes closed		Eyes open	
	Dominant	Non-Dominant	Dominant	Non-Dominant	Dominant	Non-Dominant
Phase I (preparation phase)	0.47 ± 0.31	0.37 ± 0.18	0.59 ± 0.35	0.57 ± 0.35	0.48 ± 0.08	0.52 ± 0.07
Phase II (rising phase)	0.81 ± 0.40	0.99 ± 0.53	1.34 ± 0.71	1.38 ± 0.66	0.56 ± 0.09	0.56 ± 0.14
Total duration of STS motion	1.28 ± 1.36	1.36 ± 0.55	1.94 ± 0.56	1.95 ± 0.54	1.05 ± 0.12	1.09 ± 0.12

Values are in second: mean ± SD.

Range, defined as the maximum angle minus the minimum angle, and excursion, defined as the end angle minus the start angle, were also analyzed[15].

Descriptive values (means, standard deviations) were first obtained. The normality of the distribution and the variance homogeneity were tested using the Shapiro-Wilk and the Levene's tests, respectively. One-way repeated measures analysis of variance (ANOVA) was performed to test for the effects of vision on kinematics. Two-way repeated measures ANOVA was performed to test the effects of interaction of visual-motor adaptation memory and phases of STS motion on (1) the phase durations and (2) the differences between the phase durations. If equal variances were found between the groups, Bonferroni's post hoc test was used for pair-wise comparison of the means. If unequal variances were present among the groups, Tamhane's test was used for pair-wise comparison[3]. These analyses were performed separately for the dominant and non-dominant sides. Differences were considered significant at $p<0.05$. The statistical analyses were performed using the SPSS 19.0® software.

RESULTS

On both the dominant (D) and non-dominant (ND) sides, the CB group had the lowest values and the EC group had the highest values during the preparation phase. Furthermore, the EO group had the lowest values and the EC group got the highest values during the standing phase and the total duration of the STS performance (Table 1).

In the sagittal plane, the range of motion (ROM) and the excursion of the dominant side ankle of the EC group were significantly greater than in the EO group ($p=0.042$ and $p=0.046$, respectively). In the same plane, the excursion of the non-dominant side ankle in the CB group was significantly greater than in the EO group ($p=0.038$), and the value obtained for the CB group was greater than in both the EO and the EC groups. The ROM of the dominant side knee in the CB group

Table 2. Ankle, knee, hip and trunk angles (°) of congenitally blind, eyes closed, and eyes open children in the sagittal plane of motion

	Sagittal					
	Congenital blindness		Eyes closed		Eyes open	
	Dominant	Non-Dominant	Dominant	Non-Dominant	Dominant	Non-Dominant
Ankle						
Start	82.5 ± 5.2	77.7 ± 6.6	76.9 ± 8.9	80.9 ± 9.1	85.3 ± 3.2	88.4 ± 11.2
Maximum	91.1 ± 8.9	89.3 ± 4.3	89.8 ± 9.4	91.2 ± 8.1	88.6 ± 1.9	92.4 ± 8.8
Minimum	79.0 ± 7.1	74.5 ± 5.9	73.7 ± 8.3	77.7 ± 8.8	79.9 ± 2.5	81.9 ± 8.8
End	90.9 ± 8.7	89.3 ± 4.3	89.1 ± 10.0	90.8 ± 7.8	87.6 ± 2.8	89.1 ± 5.9
Range	12.1 ± 2.7	14.8 ± 2.4	16.1 ± 5.6*	13.4 ± 4.2	8.7 ± 3.2	10.5 ± 2.9
Excursion	8.3 ± 5.1	11.6 ± 4.0*	12.2 ± 7.0*	9.8 ± 5.3	2.3 ± 4.0	0.6 ± 7.7
Knee						
Start	89.8 ± 10.5	89.6 ± 6.7	92.4 ± 5.6	91.7 ± 5.3	97.5 ± 6.7	97.5 ± 11.7
Maximum	158.1 ± 6.8	157.9 ± 6.1	168.2 ± 9.4	164.2 ± 10.8	157.9 ± 7.6	157.6 ± 4.8
Minimum	89.8 ± 10.5	89.6 ± 6.7	92.2 ± 5.7	90.6 ± 4.0	96.9 ± 6.7	97.3 ± 11.4
End	158.1 ± 6.8	157.9 ± 6.1	167.9 ± 9.7	164.0 ± 10.6	157.9 ± 7.6	157.6 ± 4.8
Range	68.2 ± 8.3	68.3 ± 9.5	75.9 ± 9.1*	73.6 ± 11.8	60.9 ± 4.5	60.3 ± 2.3
Excursion	68.2 ± 8.3	68.2 ± 2.4	75.5 ± 9.6	72.3 ± 10.9	60.4 ± 4.6	60.1 ± 9.8
Hip						
Start	103.1 ± 7.6	105.4 ± 6.4	107.2 ± 7.8	98.6 ± 6.0	103.7 ± 9.1	103.0 ± 4.9
Maximum	164.1 ± 5.3	164.0 ± 8.3	171.4 ± 6.5	159.8 ± 5.2	163.4 ± 7.6	161.2 ± 4.6
Minimum	90.7 ± 13.3	93.1 ± 9.6	92.5 ± 10.1	84.1 ± 5.4	83.6 ± 10.3	81.5 ± 7.7
End	164.1 ± 5.3	164.0 ± 8.3	170.9 ± 6.0	159.8 ± 5.2	163.4 ± 7.6	161.2 ± 4.6
Range	73.3 ± 12.7	70.9 ± 14.5	78.8 ± 10.2	75.6 ± 6.6	79.7 ± 5.4	79.6 ± 8.1
Excursion	61.0 ± 5.3	58.5 ± 8.9	63.7 ± 5.8	61.1 ± 3.2	59.6 ± 3.3	58.2 ± 3.2

Values are in second: mean ± SD.
*p<0.05 when compared to the eyes open condition

was significantly greater than in the EO group (p=0.016) (Table 2).

In the frontal plane, the EC group had the highest ankle, knee and hip ROM on the both the D and ND sides, and the ankle angle at the excursion point had the highest value among the groups. At the minimum and end point, the hip angles of the EC group had the lowest values among the groups. At the maximum point, the hip angles of the CB group had the highest values among the groups. Moreover, the EO group end-point knee angles were the lowest among the three groups (Table 3).

In the transverse plane, the EO group had the highest start point ankle values of the groups. The EO group had the lowest values for the minimum point of the thigh, the end point of the ankle, the ROM of the knee, the excursion point of the ankle and the knee angles. In addition, the EC group had the highest values for the maximum, ROM and excursion points of the knee angles (Table 4). The angles of the hip joint in all planes showed no significant differences among the groups (Tables 2–4).

DISCUSSION

This study investigated the effects of the duration of visual constraint on STS performance. Visual sensory input plays an important role in sensorimotor integration for postural balance control[16–19]. The results of this study (seat-off, after seat-off and total duration of STS motion) were consistent with some of previously conducted studies[22, 23]; however, they were not in agreement with others[15, 25]. The reason for the results of this study not being in agreement some previous studies could be the participants' age range. Some studies have reported that as age increases in children (12 to 18 months old), there is a tendency for the number of successful trials to increase, and a fall in the total duration of the STS movement[24].

Flexion initiation of the hip reflects use of hip torques to generate horizontal momentum in the initiation phase of movement[26]. This suggests that congenitally blind people and the EC subjects can successfully start STS motion. Siriphorn et al. reported that visual information affected the STS performance of EC and EO subjects[8]. However, this is contradicted by the results of the present study and those of previous studies which have reported no significant differences between the EO and EC conditions[20, 21]. These differences in results might be related to differences in neurobehavioral mechanisms between the EO and EC conditions, participant's age range and the duration of eye closure in the EC condition. Some studies have reported that the EO condition activates the attentional and oculomotor systems, while the EC condition activates the sensory cortexes (visual, auditory, and somatosensory cortexes)[8, 27–29]. It has also been demonstrated that synchronicity between the

Table 3. Ankle, knee, hip and trunk angles (°) of congenitally blind, eyes closed, and eyes open children in the frontal plane of motion

	Frontal					
	Congenital blindness		Eyes closed		Eyes open	
	Dominant	Non-Dominant	Dominant	Non-Dominant	Dominant	Non-Dominant
Ankle						
Start	124.2 ± 30.2	115.0 ± 19.9	119.9 ± 31.1	129.6 ± 23.7	122.8 ± 15.9	148.8 ± 13.6
Maximum	134.2 ± 27.3	126.4 ± 14.7	143.2 ± 30.7	143.0 ± 24.6	137.4 ± 15.9	158.6 ± 16.8
Minimum	116.6 ± 34.3	109.3 ± 19.1	119.1 ± 29.8	124.6 ± 24.1	115.3 ± 13.7	141.6 ± 15.5
End	133.3 ± 27.4	122.8 ± 11.9	133.8 ± 26.0	138.3 ± 17.3	133.7 ± 15.0	144.7 ± 15.7
Range	17.5 ± 10.8	17.1 ± 7.8	24.1 ± 14.4	18.4 ± 10.4	22.0 ± 16.7	17.0 ± 13.0
Excursion	9.04 ± 6.7	7.7 ± 12.1	13.8 ± 10.2	8.6 ± 10.3	10.8 ± 7.1	−4.1 ± 7.0
Knee						
Start	150.6 ± 14.6	167.3 ± 10.1	155.8 ± 16.3	157.3 ± 9.9	163.8 ± 9.7	162.5 ± 12.4
Maximum	179.3 ± 1.1	179.9 ±. 1	179.8 ± .17	179.2 ± 1.2	178.9 ± 1.8	178.1 ± 2.5
Minimum	150.3 ± 14.6	159.3 ± 8.6	150.2 ± 12.0	143.9 ± 29.8	162.6 ± 8.5	164.0 ± 9.2
End	176.2 ± 3.1	177.2 ± 2.8	177.3 ± 1.7	176.7 ± 1.9	176.1 ± 2.5	175.8 ± 1.1
Range	28.9 ± 13.8	16.2 ± 7.0	29.6 ± 12.0	22.8 ± 8.7	16.2 ± 9.2	20.3 ± 15.4
Excursion	25.6 ± 16.1	9.8 ± 10.3	21.5 ± 16.6	19.3 ± 11.6	12.3 ± 11.6	13.2 ± 12.1
Hip						
Start	159.8 ± 8.8	168.3 ± 3.9	157.2 ± 11.2	160.0 ± 9.67	167.4 ± 8.5	162.7 ± 11.4
Maximum	179.7 ± 0.3	179.0 ± 1.9	173.5 ± 14.1	173.8 ± 9.0	177.9 ± 2.8	177.5 ± 2.3
Minimum	159.3 ± 8.6	167.3 ± 4.8	143.9 ± 29.8	153.5 ± 15.0	164.0 ± 9.2	158.7 ± 15.3
End	174.6 ± 3.7	176.5 ± 2.6	158.3 ± 37.5	169.8 ± 11.9	175.7 ± 2.3	175.5 ± 1.4
Range	20.4 ± 8.7	11.7 ± 5.6	29.5 ± 15.9	20.3 ± 8.0	13.8 ± 7.2	18.8 ± 14.8
Excursion	14.8 ± 11.6	8.2 ± 4.5	1.1 ± 28.1	9.7 ± 13.7	8.2 ± 7.5	12.8 ± 11.5

Table 4. Ankle, knee, hip and trunk angles (°) of congenitally blind, eyes closed, and eyes open children in the transverse plane of motion

	Transverse					
	Congenital blindness		Eyes closed		Eyes open	
	Dominant	Non-Dominant	Dominant	Non-Dominant	Dominant	Non-Dominant
Ankle						
Start	7.9 ± 7.0	10.8 ± 13.3	10.2 ± 9.7	10.3 ± 10.3	10.6 ± 10.6	32.7 ± 49.9
Maximum	36.4 ± 4.6	30.8 ± 17.0	29.5 ± 24.3	48.2 ± 32.8	24.0 ± 5.2	40.0 ± 48.9
Minimum	5.0 ± 6.5	5.1 ± 8.7	3.8 ± 6.5	7.1 ± 12.1	0.6 ± 1.10	8.91 ± 7.9
End	33.7 ± 7.0	28.4 ± 17.6	27.3 ± 25.0	44.2 ± 27.2	18.1 ± 9.3	16.5 ± 5.2
Range	31.4 ± 7.8	25.6 ± 18.6	25.6 ± 25.5	41.0 ± 35.1	23.4 ± 4.7	31.1 ± 45.2
Excursion	25.7 ± 9.0	17.5 ± 24.2	17.1 ± 30.2	33.8 ± 27.6	7.4 ± 19.5	−16.2 ± 50.7
Knee						
Start	5.1 ± 4.9	12.5 ± 9.9	12.5 ± 9.8	8.3 ± 7.1	18.5 ± 16.5	33.2 ± 56.5
Maximum	22.8 ± 12.6	45.8 ± 59.8	100.4 ± 76.8	62.1 ± 62.4	19.3 ± 16.3	37.1 ± 57.8
Minimum	0.1 ± 0.1	4.84 ± 9.9	5.6 ± 7.8	4.9 ± 8.4	3.4 ± 7.4	4.3 ± 2.9
End	18.1 ± 17.4	44.9 ± 59.2	95.5 ± 73.3	58.5 ± 64.3	11.0 ± 16.0	8.9 ± 5.6
Range	22.7 ± 12.5	40.9 ± 62.2	94.8 ± 77.8	57.2 ± 64.0	15.8 ± 9.9	32.7 ± 55.6
Excursion	12.9 ± 19.5	32.4 ± 59.6	83.0 ± 74.1	50.1 ± 66.5	−7.5 ± 8.1	−24.2 ± 56.9
Hip						
Start	49.1 ± 19.9	28.5 ± 18.0	50.8 ± 39.1	40.6 ± 29.4	33.1 ± 29.4	42.5 ± 20.2
Maximum	49.1 ± 19.9	58.9 ± 52.5	100.6 ± 73.0	48.8 ± 30.9	41.4 ± 31.2	44.2 ± 16.5
Minimum	15.5 ± 9.3	9.6 ± 12.6	14.7 ± 20.1	13.7 ± 23.1	4.6 ± 7.5	0.7 ± 0.9
End	35.2 ± 10.7	52.0 ± 56.3	69.4 ± 65.6	42.5 ± 38.9	31.4 ± 32.9	10.7 ± 7.1
Range	33.5 ± 12.1	49.2 ± 47.9	85.9 ± 54.3	35.1 ± 19.9	36.8 ± 25.6	43.5 ± 16.5
Excursion	−13.8 ± 15.5	23.4 ± 55.3	18.6 ± 46.5	1.8 ± 18.6	−1.6 ± 25.9	−31.8 ± 25.0

visual, auditory, and motor systems during the EC condition is decreased, compared to the EO condition[8, 27]. In the EC condition of this study, the participants may have focused on the interoceptive state and chosen to use greater ROM and excursion for the dominant side ankle to keep themselves from falling[30] and maintain their balance[7, 31–33] and stability during standing up from the chair, compared to the EO condition. The results of present study concerning the ROM of the dominant side ankle are consistent with the study of Mak et al[26]. Furthermore, the EC subjects of this study chose greater ROM of the dominant side knee compared to the EO condition. Another possible explanation could be that the ankle and knee angles of the lower extremity had the greatest sensitivity in reaction to the present condtion[23]. In the sagittal plane, the CB subjects showed greater excursion of the non-dominant side ankle relative to the EO condition. The results of this study are not consistent with some previous studies which have reported there were no significant differences in most isometric and concentric lower limb muscles' strengths between blind and sighted subjects[8, 34]. In addition, several different loci are involved in the consolidation of biomechanical pathways, such as the hippocampus, the basolateral amygdala, and the striatum, which may process different kinds of memory[35–38]. These findings suggest that vision is the major factor influencing a muscle's ability to exert force, and that there are some differences in the biomechanical pathways of the CB and EO groups.

The present study imposed a limit on the time of eye closure for subjects in the EC group, because the participants in this study were in their early childhood, and tolerating having their eyes closed for lengthy periods of time was a little hard for them. In future research, it is recommended to verify the effects of visual constraint over, both the short (10, 20, 30 and 40 min) and long term (congenitally blind children 9, 10, 11 and 12 years old), on the performance of motor tasks.

In the sagittal plane, the ROM, the excursion of the dominant side ankle and the ROM of the dominant side knee increased with short-term vision restriction (EC group); whereas, the excursion of the non-dominant side ankle increased with long-term vision restriction (CB group). This indicates that congenitally blind children experience the problem in a part of the brain that responds to the non-dominant motor task. However, the brain could manage the challenges of the dominant side at the start of blindness during the STS movement. Moreover, at the beginning of blindness (the EC group which experienced blindness for 20 minutes), subjects adjusted the non-dominant ankle excursion and could successfully complete a STS, while after 94 months of blindness they could not regulate the non-dominant side ankle excursion.

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