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Comparative study

The effect of time restricted visual sensory input on asymmetry of ground reaction force components in female children

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ABSTRACT

The association between visual sensory and the asymmetry index of sit-to-stand ground reaction force characteristics is not fully understood. Therefore, the purpose of this study was to investigate asymmetry index of sit-to-stand ground reaction forces, their times–to-peak, vertical loading rate, impulses, and free moment in blind and sighted children. 15 female children with congenital blindness and 30 healthy girls with no visual impairments volunteered to participate in this study. The girls with congenital blindness were placed in one group and the girls with no visual impairments were randomly divided into two groups of 15. The two condition groups consisted of, one eyes open and the other, eyes closed. The participants in the eyes closed group were asked to close their eyes for 20 min before the test, whereas those in the eyes open group kept their eyes open. Kinematic and kinetic data were collected using an eight-camera motion analysis system synchronized with two force plates embedded in the floor. A MANOVA test was run for between-group comparisons. There were no distinctive biomechanical alternations in all axes of ground reaction forces and their times-to-peak, vertical loading rate, impulses and free moments in congenital blindness and eyes closed groups compared with the eyes open group. However, eyes closed was associated with increased total time and second phase duration of sit-to-stand performance by 69% ($p = 0.008$) and 62% ($p = 0.008$), respectively. These findings reveal that individuals who are visually restricted in the short term, do not develop stereotypical movement strategies for sit-to-stand.

1. Introduction

Standing from a chair requires continuous control of various sensory signals. The body segment movements are detected by the visual, vestibular, and somatosensory systems. The central and peripheral nervous systems integrate sensory information, regulate joint moments and activate muscles(Fujisawa et al., 2005). It has been demonstrated that visual information plays an important role in the postural stability (Bardy et al., 1999; Tomomitsu et al., 2013; Hill et al., 2016). Visual sensory input collects accurate spatial information about the ongoing body position to influence postural stability(Easton et al., 1998). In the normal pattern of sit-to-stand (STS), the trunk starts to flex forward before seat-off, the center-of-pressure (COP) displaces backward, and the center-of-mass (COM) accelerates forward(Mourey et al., 2000; Schenkman et al., 1996; Kerr et al., 1997; Gross et al., 1998; Kralj et al., 1990). After seat-off, the COM decelerates and COP transfers forward(Schenkman et al., 1990, 1996; Hughes et al., 1994a). At the end of the movement, the vertical loading rate turns back to an approximately constant level, which corresponds to the subject's weight (Talis et al., 2008). According to these studies, biomechanical variables of the STS, can provide more information about the effect of restricted visual sensory input for postural balance control.

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The STS transition is a mechanically demanding task(Manckoundia et al., 2006) and one of the basic motor activities(Talis et al., 2008; Kong et al., 2012; Magnan et al., 1996; Jones et al., 2016) that may pose particular challenges for individuals with constrained visual information. Furthermore, STS is a standard test to assess a functional deficient in persons with restricted visual sensory input(Siriphorn et al., 2015; Kuramatsu et al., 2012). Normal adults stand up from a chair approximately 60 times each day(Dall and Kerr, 2010) and many groups of people who experience difficulty doing this task including older adults, those with total joint replacement, pregnant women, and obese individuals(Chen et al., 2011; Hughes et al., 1994b; Hennington et al., 2004; O'Meara and Smith, 2006; Reider and Gaul, 2016; Goldberg, 2012; Huffman et al., 2015; Kuramatsu et al., 2012; Munro et al., 1997; Highsmith et al., 2011; Lomaglio and Eng, 2005). As such difficulties influence the quality of daily life and ability to remain independent, research on the STS movement is essential. Biomechanical characteristics of the STS task have been an area of particular focus, since it is one of the most demanding and important daily activity (Hodge et al., 1989; Ploutz-Snyder et al., 2002; Rodosky et al., 1989). The STS task needs a higher amplitude of peak joint moment than other daily tasks such as stair ascending or walking(Rodosky et al., 1989). STS also yields greater peak hip joint contact pressure than other activities such as walking, jogging, or even jumping(Hodge et al., 1989).

It is well documented that individuals with restricted visual sensory input exhibit movement dysfunction. For example, restricted visual sensory input can lead to balance disorders(Singh et al., 2012; Portfors-Yeomans and Riach, 1995; Schmid et al., 2007; Giagazoglou et al., 2009), varieties of sensorimotor strategies(Easton et al., 1998; Anjos et al., 2016) and also sensory integration disorders(Wolsley et al., 1996) during functional tasks. Blind individuals produce greater center of gravity sway(Siriphorn et al., 2015), muscular strength and power(Horvat et al., 2006), difference in angular displacement in the sagittal plane(Aylar et al., 2016) and need assistance when performing the STS task. Moreover, it is reported that a constrained visual sense is independently associated with weight bearing ability(Talis et al., 2008), COM velocity(Kuramatsu et al., 2012), rising index(Siriphorn et al., 2015), and total time duration of STS performance(Aylar et al., 2016; Talis et al., 2008). Asymmetry index (AI) of kinetic parameters during STS, could provide clinical significance and be used to provide useful feedback for evaluating treatment results or for designing rehabilitation programs.

Weight-bearing asymmetry during STS was assessed indirectly as a difference of vertical ground reaction force (GRF), in the affected leg, of the patients with total hip anthroplasty(Talis et al., 2008) and individuals with unilateral, lower limb, musculoskeletal pathologies(Abujaber et al., 2015; Highsmith et al., 2011; Roy et al., 2006). Furthermore, the asymmetry of vertical GRF during STS can be affected by foot placement(Roy et al., 2006; Gillette and Stevermer, 2012). Based on the author's knowledge, the asymmetry of GRF data during STS in blind individuals was not evaluated from a scientific view.

Among the STS parameters, asymmetry of GRF is of greater importance due to higher reliability(Schofield et al., 2013; Eitzen et al., 2014). The AI of STS ground reaction forces, their time-to-peak (TTP), vertical loading rate, impulses and free moment (FM) are among the most important kinetic variables that could affect a functional movement. A few studies have focused on STS analysis of visual constrained sensory(Talis et al., 2008; Siriphorn et al., 2015; Kuramatsu et al., 2012), then calculating of asymmetry of STS ground reaction force characteristics can be one of noticeable step toward understanding of visual rehabilitative training and interventions could possibly help to improve physical functioning. However, there is a paucity of research examining of the GRF during STS movement in individuals with congenital blindness. The aim of the present study was to analyze the AI of GRF, their TTP, loading rate, impulses in all axes, and FM during STS in children with congenital blindness (CB) and healthy children with eyes closed (EC) and eyes open (EO). We hypothesized that time of visually restricted information (short and long term) is associated with altered biomechanical strategies of STS.

2. Materials and methods

2.1. Participants

Forty-five female children, with permission of their parents, were recruited to participate in this study. A prior statistical power analysis, using G*Power program, revealed that for a statistical power of 0.80, at an effect size of 0.80, and an alpha level of 0.05, a sample size of at least 14 participants was required(Faul et al., 2007). CB children were selected from blind schools (Taghva) in Mashhad, Iran. In this experiment, blindness is defined as visual acuity of less than 3/60 (20/400 or 0.05) or a corresponding field not greater than 10 in the better eye, with best possible correction(Pascolini and Mariotti, 2012).

The CB group included 15 girls suffering from congenital blindness. The remaining 30 girls were healthy and did not have any visual impairment. These 30 healthy individuals were divided into two different condition groups. The subjects in the EC group, closed their eyes for 20 min before the STS test, while the EO group kept their eyes opens. During practice and actual trials, the subjects in the EC group kept their eyes closed to prevent any possible learning from taking place by receiving visual information. The blind girls were physically active in daily life and merely suffered from blindness. Subject selection was based on the following criteria: female, between the ages of 84–108 months, no history of musculoskeletal or neuromuscular dysfunction such as flat feet and drooping shoulders, having BMI between 13 and 20 kg/m^2(Schaefer et al., 1998), and being physically active in daily life. Exclusion criteria consisted of any history of ligament injury, surgery in either of the lower extremities, feelings of fatigue, history of regular athletic trainings, inability to complete the research protocol, recent history of growth spurts that could affect the results, and participation in heavy physical tasks or exercise during the past two days. Subject age, mass, height, body mass index (BMI), leg length, anterior superior iliac spine (ASIS) width measurements, along with the dominant side in anterior-posterior, medial-lateral, and vertical axes, and time duration of STS performance, are summarized in Table 1. There was no significant difference between the groups for age, mass, height, BMI, leg length, and ASIS width. The dominant limb was determined as the limb used to kick a ball(-Burnett et al., 2011). Participants and their parents were fully informed about the aims and protocol of the study and signed an informed consent. Ethics approval was obtained from the research council of the International University of Imam Reza, and informed consent forms obtained from the children's parents.

2.2. STS kinematic analysis

An eight-camera, video-based, optoelectronic system, (Qualisys AB, Sweden) at a sampling rate equal to 100 Hz, was used for three-dimensional motion captures. The motion capture data was filtered using a fourth-order Butterworth filter with a cutoff frequency of 10 Hz(Highsmith et al., 2011). Retro-reflective markers were placed over bony landmarks, including the vertex, seventh cervical vertebra (C7), and the spinous process of the twelfth thoracic vertebrae. Markers were also placed bilaterally, on the lateral

Table 1
Demographic and clinical characteristics of congenitally blind, eyes closed, and eyes open children.

	Groups			Sig.
	Congenital blindness	Eyes closed	Eyes open	
N	15	15	15	NA
Age (month)	94.60 ± 5.59	93.80 ± 5.89	95.80 ± 5.54	0.856
Mass (kg)	25.74 ± 2.12	24.16 ± 1.35	26.06 ± 5.22	0.641
Height (m)	1.27 ± 0.05	1.24 ± 0.04	1.26 ± 0.04	0.632
BMI	16.13 ± 2.55	15.66 ± 0.83	16.11 ± 2.05	0.912
Gender	Female	Female	Female	NA
Leg length (cm)	36.62 ± 1.59	34.56 ± 1.13	36.16 ± 1.55	0.100
ASIS width (cm)	17.76 ± 1.23	15.84 ± 0.64	16.46 ± 0.95	0.25
Foot dominant side	R	R	R	0.756
Phase I duration of STS task	0.36 ± 0.23	0.44 ± 0.23	0.40 ± 0.17	0.628
Phase II duration of STS task	0.84 ± 0.36	1.21 ± 0.52*	0.75 ± 0.26	0.007
Total duration of STS task	1.21 ± 0.41	1.66 ± 0.51*	1.15 ± 0.25	0.002

Note: Values are mean ± standard deviation. Abbreviations: N, number of participants; BMI, body mass index; R, right; ASIS, anterior superior iliac spine; NA, not applicable; STS, sit-to-stand.
*$p < 0.05$ when compared to the eyes open condition.

border of the acromion process, head of the humerus, olecranon process of the ulna, head of the styloid process of the ulna, ASIS, posterior superior iliac spine (PSIS), greater trochanter, lateral femoral epicondyle, lateral malleoli, 5th distal metatarsal head, and calcaneal tuberosity. Before performing the tests, all 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(Roy et al., 2006). During the STS test, the participants placed one foot on each force plate for 3–4 s(Kerr et al., 1994), their arms were folded across the chest. The subjects sat with their bodies and lower extremities symmetrically placed relative to the chair, and the distance between the feet was determined by the ASIS width. The subjects in EO group were instructed to place their feet within the outer limits of the two force plates, one foot on each plate. In addition, the subjects were asked to use a self-selected movement strategy. The subjects were instructed to raise their entire body from the chair at a self-selected velocity, and to remain standing, after reaching the upright position, for 3–4 s(Kerr et al., 1994). Each subject was asked to perform five STS trials, with 30 s rests between trials, after having practiced three times prior to recorded trials. Upper extremity markers were used to define STS events. Markers on the olecranon and the styloid processes of the ulna, were used to monitor the arms folded across the chest, because all of the participants were children in this investigation.

The task of STS was defined by three events: (1) the beginning of the movement when the border of the acromion process 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, which 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.

2.3. STS kinetic analysis

Two adjustable force plates, (9260AA6, Kistler, Switzerland) were used to record the GRFs during the performance of the STS task, at a sampling frequency of 1000 Hz (Jafarnezhadgero et al., 2017c). The GRF data were filtered using a fourth-order Butterworth filter with cutoff frequency of 10 Hz(Highsmith et al., 2011). The GRF values were recorded along vertical (z), mediolateral (x), and anterior-posterior (y) directions (see Fig. 1). The vertical GRF curve in normal STS contains one peak on the preparation point (Fz_{PP}) and minimum amplitude on the standing point (Fz_{SP}). Moreover, on the anterior-posterior curve, two peaks were recorded at the preparation reaction force (Fy_{PP}) and standing points (Fy_{SP}). From the mediolateral curve, three values were recorded corresponding to the preparation point (Fx_{PP}), which occurred initially (Fx_{PP}), followed the peak at the middle (Fx_{MS}) and minimum amplitude on the standing point (Fx_{SP}) at the final part of curve. The loading rate was defined as the slope between the initial and Fz_{PP} on a vertical GRF curve (see Fig. 1)(Munro et al., 1987; Jafarnezhadgero et al., 2017d). Impulse was calculated for all axes (Impulse z, Impulse y, Impulse x) based on the trapezoid integration method (see Fig. 1)(Robertson et al., 2013), and the peak positive and negative FM amplitude were also calculated(Almosnino et al., 2009). All GRF and FM values were normalized with respect to the body weight (BW) and BW × Height, respectively (Jafarnezhadgero et al., 2017a).

2.4. STS asymmetry index

For all groups, the STS asymmetry (STSA) was calculated based on the study by Su et al. (2015):

At the STSA formulae, X_L stands for the related variable in left lower limb and X_R stands for the related variable in right lower limb. For perfectly symmetric STS, the optimal value for the asymmetry index is 0. Larger asymmetry index represents less symmetric STS patterns.

$$STSA = \frac{|X_L - X_R|}{2|X_L + X_R|}$$

2.5. Statistical analysis

Data distribution was tested for homoscedasticity using the Levene's test. A MANOVA test was performed for between-group comparisons ($P < 0.05$). 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 tests was used for pair-wise comparison(Highsmith et al., 2011) by the number of potentially dependent variables ($p < (0.05/\text{number of parameters})$). Statistical analysis was performed using the SPSS 19.0® software. The effect sizes (d) were calculated as a ratio of mean difference divided by the mean standard deviation of both related groups. In addition, we

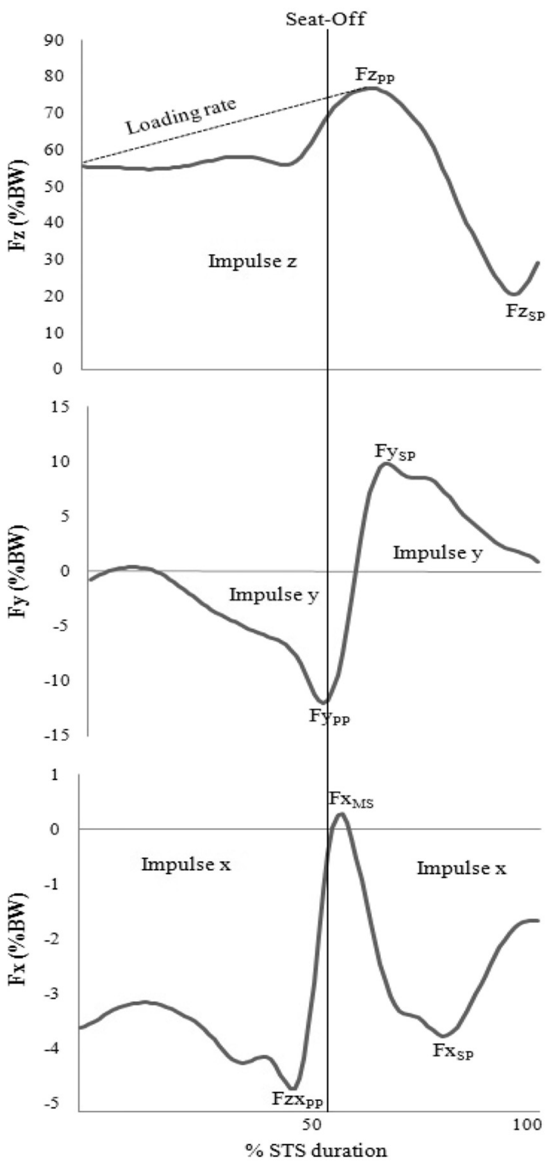

Fig. 1. A time-normalized sample traces of the ground reaction forces of a normal subject during STS task. Reaction forces and impulse areas in all axes and vertical loading rates are displayed. Seat-off event is indicated by the solid vertical line.

interpreted effect size as trivial ($d < 0.2$), small (≥ 0.2 to < 0.5), moderate (≥ 0.5 and < 0.8), or large (≥ 0.8)(Cohen, 1988).

3. Results

There were no statistically significant differences between the groups for age, mass, height, BMI, leg length, and ASIS width (see Table 1). Whereas, the durations of STS performance had significant differences between groups ($P = 0.016$). The total duration of STS performance in the EC group were significantly greater at 69% ($p = 0.008$, $d = 1.32$) in the EO group. Also, the EC group displayed greater standing phase (phase 2) time duration by 62% ($p = 0.008$, $d = 1.16$) than those in EO group (see Table 1). The time duration of preparation phase (phase 1) was similar among groups ($p > 0.05$).

AIs of GRF variables for all groups is presented in Table 2. The AI values of GRF components were similar among the three groups ($p = 0.441$).

Table 3 shows the AI of TTP of GRF components in all groups. AI of TTP variables among groups were not significantly different ($p = 0.060$).

The AIs of impulse values ($p = 0.068$) (see Fig. 2A) in the CB, EC, and EO groups were similar. Vertical loading rates (see Fig. 2B) have significant differences among groups ($P = 0.040$), but there are not any significant differences between participants ($p > 0.05$).

The AIs of peak negative and positive free moments ($p = 0.398$) (see Fig. 3A) and free moment amplitudes during of phase 1 and phase 2 ($p = 0.378$) (see Fig. 3B) did not demonstrate any significant differences between the all groups.

Table 2
Asymmetry index (AI) of ground reaction forces (GRF) of X, Y, and Z axes in different sit-to-stand (STS) points for congenitally blind, eyes closed, and eyes open groups. Data are (mean ± SD).

AI-GRF	Groups		
	Congenital blindness	Eyes closed	Eyes open
Fx_{PP}	15.563 ± 35.566	15.706 ± 30.978	6.571 ± 6.894
Fx_{MS}	2.153 ± 2.583	10.667 ± 27.071	4.843 ± 9.889
Fx_{SP}	3.042 ± 3.921	46.966 ± 121.805	6.295 ± 7.332
Fy_{PP}	0.480 ± 0.990	0.463 ± 0.584	0.251 ± 0.217
Fy_{SP}	2.457 ± 6.192	0.244 ± 0.225	0.184 ± 0.126
Fz_{PP}	0.053 ± 0.029	0.034 ± 0.037	0.053 ± 0.043
Fz_{SP}	0.162 ± 0.137	0.114 ± 0.124	0.136 ± 0.142

Table 3
Asymmetry index (AI) of time-to-peak (TTP) of ground reaction forces (GRF) components for congenitally blind, eyes closed, and eyes open groups. Data are (mean ± SD).

AI-TTP	Groups		
	Congenital blindness	Eyes closed	Eyes open
Fx_{PP}	0.077 ± 0.115	0.086 ± 0.059	0.080 ± 0.110
Fx_{MS}	0.084 ± 0.074	0.086 ± 0.060	0.014 ± 0.011
Fx_{SP}	0.050 ± 0.047	0.057 ± 0.045	0.025 ± 0.020
Fy_{PP}	0.081 ± 0.094	0.042 ± 0.055	0.027 ± 0.021
Fy_{SP}	0.068 ± 0.087	0.037 ± 0.032	0.018 ± 0.014
Fz_{PP}	0.120 ± 0.109	0.097 ± 0.069	0.066 ± 0.063
Fz_{SP}	0.034 ± 0.043	0.055 ± 0.048	0.016 ± 0.036

4. Discussion

The aim of this study was to better understand the effect of the time constraint of vision on the asymmetry of ground reaction force components in children. Asymmetric ground reaction force components between the lower limbs during STS performance are a marked feature in individuals with neuromuscular and musculoskeletal problems(Skelton et al., 2002; Kneiss et al., 2015; Highsmith et al., 2011). We hypothesized that the time of restricted visual sensory input would increase the overall GRF asymmetry when compared to rising from a chair, while receiving full visual sensory input. We did not find any significant difference among groups for all of GRF asymmetry parameters. This does not prove the hypothesis of this study and reveals that; the lack of short and long term visual memory cannot alter the asymmetry of GRF components. To this author's knowledge, this work provides the first reference database of asymmetry of STS ground reaction force characteristics in congenitally blind and acute loss of visual sensory input female children.

In the present study, the AI values of vertical, anterior-posterior, and mediolateral GRF components were similar among the three groups. It is also possible that the similar number of anterior-posterior GRF difference were also due to same stride velocities between right and left limbs(Eggleston et al., 2017). If right and left limb stride velocities were significantly different, it may have

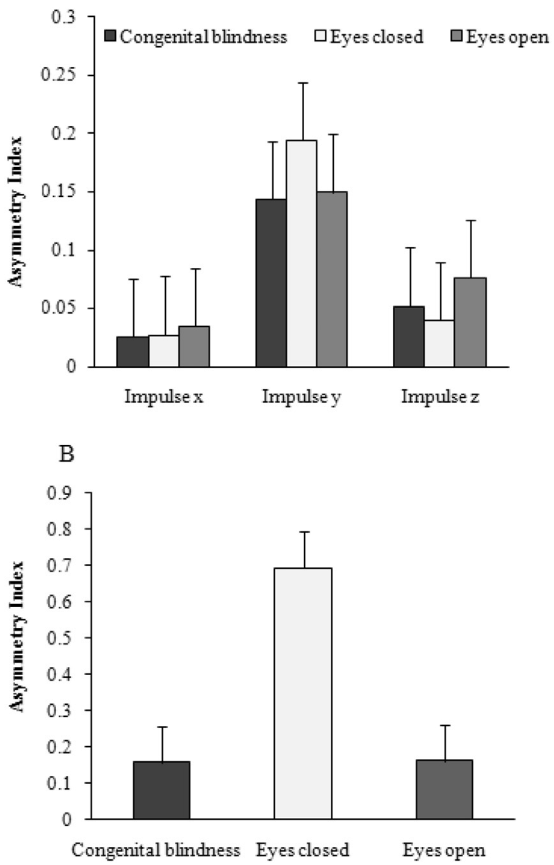

Fig. 2. Asymmetry indices of (A) impulse values and (B) vertical loading rates in the congenitally blind, eyes closed, and eyes open groups.

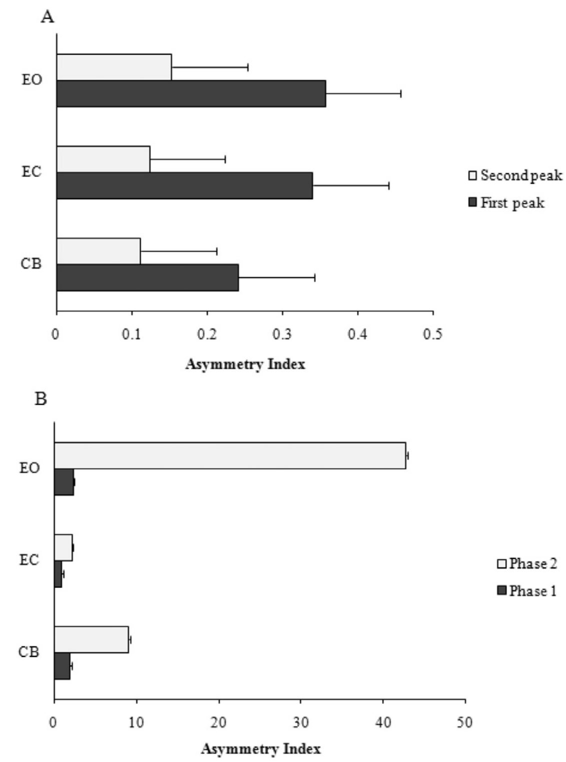

Fig. 3. Asymmetry indices of (A) negative and positive peaks of free moment curve of dominant side and (B) the free moment of non-dominant side in the control and experimental groups during phase 1 and phase 2.

altered the lower extremity joint contributions to anterior-posterior propulsive and braking force attenuation, while the vertical GRF differences were derived primarily from gravity(Eggleston et al., 2017). An asymmetrical functional movement pattern can increase energy expenditure(Zamparo et al., 1996) and risk of falls(Fabio et al., 2004) between individuals. However, our results did not demonstrate any significant difference among three groups in GRF component AI. Nonetheless, further study is warranted to support or refute this postulation. In this study, the asymmetry index of the CB group was similar to the EO group, but their patterns didn't overlap accurately with the EO group. Some studies reported that foot orthoses(Jafarnezhadgero et al., 2017b; Kutilek et al., 2014), chair height(Rocha et al., 2010) and foot placement(Roy et al., 2006; Brunt et al., 2002) can decrease GRF asymmetry during functional movements. Therefore, the controlling of this disorder by different interventions may prevent asymmetry-induced injuries in blind individuals. Nevertheless, to prove this hypothesis, further investigation is needed.

It has previously been reported that the compensatory effect is much greater if sight deprivation occurs early in life(Völgyi et al., 1993). Therefore, the possibility that congenitally blind individuals performed balance tasks better than acute loss of visual sensory input individuals seem a possible assumption. The results of the present study showed that higher time duration of standing phase and total performance of STS between the EC group in comparison to the EO group, which also supports the hypothesis of this study. Also, it illustrates that vision cannot be replaced by other sensory inputs(Schmid et al., 2007). In the absence of visual information, the vestibular and somatosensory data are acting relatively the same both in congenitally blind and acute loss of visual sensory input individuals (Ray et al., 2008). Also, it has been demonstrated that vision plays a dominant role in the coding and processing of other sensory information(Paulus et al., 1984).

In the present study, we did not find any significant difference in asymmetric limb loading between the EO and EC groups. Many studies documented that visual sensory provides additional dynamic and body configuration information for improving motor performance(D'Hondt et al., 2011; Hallemans et al., 2010; Helbostad et al., 2009; Courtemanche et al., 1996; Ghez et al., 1995). It seems that visual information in short term restricted visual memory, could be used for controlling postural stability and/or general characteristics of movement, rather than for updating the pre-existing central motor programs for weight-bearing ability during STS maneuvers. Accordingly, our results suggest that short term restricted visual cues play only a minor role in the control of weight bearing asymmetry in acute loss of visual sensory input children. Furthermore, dark adaptation for the visual system is the process of adjusting to total darkness or to lower levels of illumination(Held, 1998). The time of rod intercept reported is less than or equal to 20 min, usually 8.2 min(Jackson and Edwards, 2008) and 12.5 min(Holfort et al., 2010), in young and elderly people, respectively. In addition, it was proved that the consolidation process of a new motor memory may take several hours(McGaugh, 2000), or under certain circumstances minutes(Podolski, 1998). The findings of this study indicate that the consolidation process occurred during rod intercept for asymmetry of GRF components.

The vertical loading rate is a vital variable for evaluating the overload of lower limb musculoskeletal tissues(Liikavainio et al., 2010; Silva et al., 2015; Farahpour et al., 2017). A vertical loading rate more than 70, 72 and 100 N/(kg.s) is one of the risk factors for stress fractures (Crowell and Davis, 2011), patellofemoral pain

(Cheung and Davis, 2011), and plantar fasciitis(Pohl et al., 2009), respectively. In addition, the FM corresponds to the torque about the vertical axis exerted on the center of pressure of the foot(-Holden and Cavanagh, 1991). Furthermore, the FM can be used as a possible predictor of tibial stress fracture(Milner et al., 2006). In the present study, results did not show any significant differences in asymmetry of vertical loading rate, impulse amplitudes, negative and positive peaks of FM, and FM amplitudes during preparation phase and standing phase among three groups. Therefore, it can be suggested that blind children have obtained some compensatory strategies that reduce the number of asymmetry-induced injuries during rising from a chair. Looking at children has some complications, where continual growth and development can make for an ever-changing landscape and may lead to transient asymmetries. Therefore, we are not able to infer the response of children to an adult population.

There are some limitations that should be noted within the present study, most notably, the ability to both functionally classify joint asymmetry and estimate it by different variables over the entire STS task is reflected in the association between joint function, pathology, and gender differences. Since the current study, to our knowledge, is the first to investigate the effects of blindness on STS mechanics in female children, future studies, involving a larger cohort and across a wider spectrum of ages, genders, and methodological considerations may be warranted.

5. Conclusion

Long term constrained vision results in a significant increase of asymmetry in time-to-peak of mediolateral ground reaction force. Also, short-term restriction of vision leads to increase in sit-to-stand time duration. Moreover, results did not show any significant differences in asymmetry of vertical loading rate, impulse amplitudes, and negative and positive peaks of FM among three groups. Therefore, it can be suggested that blind children have learned compensatory strategies, which lead to a reduction in the number asymmetry-induced injuries, while standing from a chair.

Conflict of interest

None of the authors have any conflicts of interest in relation to the work reported here.

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