Journal of Advanced Sport Technology 4(1):61- 71 Received: January. 31, 2020; Accepted: May. 24, 2020

Original Research

The Spatiotemporal Parameters of Stair Locomotion in Individuals with Congenital Sight Loss and Full-sight

Jamshid Nouri Ghafar[1], Mahdi Majlesi[2*], Elaheh Azadian[3], Amir Fatollahi[4]

1. *Department of Sport Biomechanics, Faculty of Humanities, Islamic Azad University, Hamedan Branch, Hamedan, Iran. Email: jamshid.norighafar@gmail.com, ORCID: 0000*-0003-0265-8327
2. *Department of Sport Biomechanics, Faculty of Humanities, Islamic Azad University, Hamedan Branch, Hamedan, Iran. Email: majlesi11@gmail.com, ORCID: 0000*-0003-2032-4937
3. *Department of Motor Behavior, Faculty of Humanities, Islamic Azad University, Hamedan Branch, Hamedan, Iran. Email: azadian1@yahoo.com, ORCID: 0000*-0002-0114-9208
4. *Department of Physical Education and Sport Sciences, Faculty of Educational Science and Psychology, University of Mohaghegh Ardabili, Ardabil, Iran. Email: amiraf14618@gmail.com, ORCID: 0000*-0002-0192-4358

ABSTRACT

Stair ascent and descent is a challenging task for people with sight loss. Identifying the effects of lack of visual input in people with sight loss while stair ascent and descent can be effective in planning rehabilitation program and improving locomotion pattern. The purpose of the present study is to evaluate the spatiotemporal variables in stair ascent and descent in people with sight loss and comparing them with people with full-sight. In this study, the spatiotemporal variables of stair ascent and descent in people with sight loss were measured using 3D motion analysis device Vicon with frequency of 100HZ. For within group analysis, repeated measure test and for that of between groups, independent sample t-test were used with level of significance of $p<0.05$. The spatial-temporal gait parameters during stair ascent and descent were collected. The results showed that the people with sight loss had less speed, cadence and stride length comparing with people with full-sight ($p<0.05$). Moreover, stride and step time, single and double support time and stance time were significantly more in people with sight loss comparing with the people with full-sight ($p<0.05$). There was a significant difference in variables such as cadence and stance time between stair ascent and descent ($p<0.05$) and in both groups the mentioned difference was the same ($p>0.05$). Decreased speed and cadence and increased stance time represent motion deficiency in people with sight loss. Regarding the mentioned results, people with sight loss have cautious stair locomotion pattern and spatiotemporal variables in closed eye state in people with full-sight had weaker patterns comparing with people with loss sight.

Keywords: Sight loss, Spatiotemporal variables, Stair ascent and descent, Open and closed eyes.

Corresponding Author: Mahdi Majlesi, Department of Sport Biomechanics, Faculty of Humanities, Islamic Azad University, Hamedan Branch, Hamedan, Iran. E-mail: majlesi11@gmail.com, Tel: +98 918 407 7540, Fax: +98 813 449 4042

Introduction

Blindness is a state in which the individuals do not have any sight perception (1). Visual inputs in the neuromuscular response process of the central nervous system have an important role in various motor tasks, so that sight loss can cause deficiency in bodies' consistency and balance (2) which is one of the reasons of fall in people with sight loss or the people with visual deficiency (3,4). Lack of visual input can have a big influence on gait mechanics so that, lack of visual inputs in people with sight loss affects gait pattern (5). Biomechanical studies on gait in people with sight loss were confined to gait speed, stride length, cadence (3, 6,7,8), the effect of using cane for orientation, as well as motion and related exercises (9). Posture control weakness, poor balance, gait problems (10), and vision problems (3) are significant causes of falling and injury in people with sight loss. One of the daily tasks of people's routine is stair ascent and descent (11,12). The previous studies suggested that while ascending and descending the stairs, body balance and posture control have some changes comparing with gait on flat surface (13, 14). Therefore, people with balance control impairment such as the elderly (15), patients suffering from Parkinson's disease (16), and knee joint Osteoarthritis (17) have some problems in this task. On the other hand, the previous studies on people with full- sight showed that stair ascent and descent needs high range of motion in lower limb joints and moments in the mentioned joints (18). Through identifying biomechanical characteristics of stair ascent and descent in people with sight loss, essential information on kinetic and kinematic variables of this task can be specified and the fall risk in these people can be decreased. The research showed that 10% of the causes of death in people with sight loss is stair fall (19). Research on characteristics of spatiotemporal variables of stair ascent and descent was conducted in limited studies (2, 17, 20-22). Identifying the effects of lack of visual input in people with sight loss while stair ascent and descent can be effective for designing novel equipment for improving locomotion pattern. The present study is aimed at evaluating spatiotemporal variables of stair ascent and descent in people with sight loss. Consequently the hypothesis of this paper is lack of visual input in people with sight loss can affect the spatiotemporal variables of stair ascent and descent.

Materials and methods

We used the freeware tool G*Power (http://www.gpower.hhu.de/) and priori power analysis to calculate the number of samples. For this purpose, we assumed a Type I error of 0.05, a Type II error rate of 0.20 (80% statistical power), and an effect size of 0.80 based on the findings of a previous study (1). The analysis revealed that 20 individuals are sufficient to observe the large between-group differences. Therefore, in this study, twelve men with sight loss as experimental group and 12 men with full-sight as control group among university students of Hamedan voluntarily participated in the study (23). The subjects of experimental group were born blind and did not have any conception towards light. People in both groups did not have any continuous exercise history during the last 2 years. People who had some injuries in their lower limb or suffered from neurological disease (muscle disease) and orthopedical ones (bone fracture, tendonitis, sprain, strain, and joint surgery) over the last 6 month, were set aside from the study. The subjects also filled permission form for participation in the test, and then the stages of the test, methods of measuring variables and the whole method were completely described for the subjects. The Research Commission of Islamic Azad University of Hamedan approved the protocol of this study on May 22, 2018 with 5734/3/97 number.
A six camera Vicon system (Oxford Metrics, Oxford, UK) was used to record three-dimensional lower-body kinematic data (100 Hz) to identify the spatiotemporal variables of stair ascent and descent. For this purpose, 16 retro-reflective markers were connected to the anatomical points at both lower limbs of the participants, based on the Plug-In Gait Marker Set (Vicon Peak, Oxford, UK) (24, 25). In this research ascending and descending 4 stairs which were 0.18m high, 0.28m deep and 1.20m wide was considered as the task of the subjects. Each subject was supposed to walk at least 7 steps to reach the stair and walk on it (26). The people with sight loss passed the route bare feet, with normal speed and without using any cane. The subjects of another group did the task under 2 conditions: a) stair ascent and descent with open eyes, b) stair ascent and descent with closed eyes. In each given variable, the average of repeating 3 times was considered for statistical calculations. Then the variables such as cadence, gait speed, stride length, step length, stride time, step time, stance time, swing time, single support time, and double support time were extracted (Fig. 1)(27). In this study, swing time of each foot was equal to single support time in the other foot (28, 29), which were calculated from extracted data by (Vicon software Polygon Oxford Metrics Ltd, Oxford, UK). The stance time was also calculated with formula 1. Calculating stance time x for each foot (right and left) was done separately.

formula 1) Stance time x = double support time x + single support time x

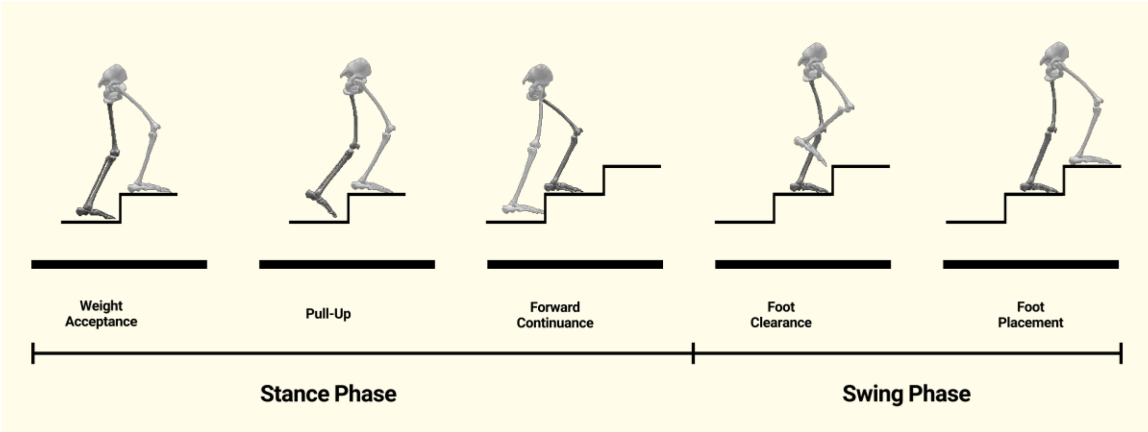

Figure 1. Sub-phases of one complete gait cycle in stair walking. (1) weight acceptance (ipsilateral foot-strike to contralateral toe-off), (2) pull-up and (3) forward continuance (contralateral toe-off to contralateral foot-strike), (4) early swing and foot clearance and (5) late swing and foot placement (ipsilateral toe-off to ipsilateral foot-strike) [1] .

Firstly, the normality of the variable distributions was verified using Shapiro-Wilk test. All data had normal distribution. The research had 3 factors; Task (with 2 levels of stair ascent and descent), Vision (with 2 levels of closed and open eyes) and foot (with 2 levels of right and left foot) and as a result, performing Repeated measure test was required. For studying each research variables, a distinct test was given. An independent sample T-test was used for studying and identifying the difference between groups. The calculations were done by SPSS (version 16.0), (Chicago, IL, USA), the statistical significance was assessed at $p<0.05$ level.

Results

The results related to demographic characteristics of the subjects are shown in Table 1.

Table 1. Demographic characteristics of individuals with full-sight and with sight loss.

	Groups		Sig.
	Sight loss	Full-sight	
N	12	12	NA
Age (year)	26.40±5.59	21.91±2.93	0.07
Mass (Kg)	66.80±17.37	73.61±17.38	0.39
Height (cm)	1.69±0.07	1.77±0.08	0.06
BMI	23.14±5.24	23.23±3.98	0.96
Gender	Male	Male	NA

Note: Values are mean ± standard deviation. Abbreviations: n, number of participants; BMI, body mass index; NA, not applicable.

The results of statistical analysis about speed showed that the speed of stair ascent and descent was the same in both groups. The findings suggested that the main effect of vision was significant (F (22)= 65.4, p= 0.001, Eta = 0.75). The results of comparison within groups showed that the speed of stair ascent and descent in people with full-sight in closed eye condition was significantly less than that of open eye condition ($p<0.05$).
The results about the cadence pointed out that the factors of task (p= 0.002) and vision (p = 0.0001) had significant influence on cadence, and based on the results, the cadence was significantly lower in stair ascent comparing with stair descent and also in open eye condition, it was more than that of closed eye condition. A comparison between two groups showed that cadence in group with full-sight in open eye condition was significantly more, comparing with group with sight loss but by closing eyes, cadence of people with sight loss became more than the ones with full-sight. Stride time and step time in closed eye condition was more

comparing with the open eye condition (stride time, $F(22) = 32.8$, $p= 0.001$, Eta = 0.6, step time, $F(22)= 31$, $p= 0.001$, Eta= 0.58). The results of comparison between groups showed that there is a significant difference between 2 groups in closed eye and open eye condition. So that the time of stride and step in people with full-sight in open eye condition was less comparing with people with sight loss. While having the eyes closed, the time of stride and step was significantly more in people with full-sight comparing with the ones with sight loss. The results considering single support time suggested that main effect of vision had a significant effect on this variable ($F(22)= 17.3$, $P= 0.0001$, Eta= 0.44). These results showed that single support time in closed eye condition had a significant increase comparing with the open eye one ($F(22) = 17.3$, $P= 0.002$, Eta= 0.61). The comparison between groups also pointed out that the difference between two groups referred to single support time in closed eye condition and while stair ascent, which was more in people with full-sight. The results of factor analysis in double support time indicated that the factor of task had a significant effect on this variable ($F(22)= 9.1$, $P= 0.006$, Eta = 0.29). The averages show that double support time in stair ascent is significantly more than stair descent. Moreover, the factor of vision had a significant effect on double support time ($F(22) = 33.2$, $P= 0.0001$, Eta= 0.6). The result of comparison within groups indicated that by closing the eyes in people with full-sight, the single support time showed a significant increase comparing with open eye condition ($F(11)= 33.24$, $P= 0.001$, Eta= 0.75). The comparison between groups also showed that double support time had significant difference merely in stair ascent between people with sight loss and full-sight ($P< 0.05$). While, in stair descent it did not show a significant difference between 2 groups. The results on stance time showed that the factor of task is significant in this variable. ($F(22) = 6.8$, $P= 0.016$, Eta= 0.24). Considering the results within the groups, it could be identified that stance time in people with sight loss in stair ascent and descent did not have a significant difference ($F(11)= 1.1$, $P= 0.31$, Eta = 0.09), but in the group with full-sight , the stance time in stair ascent was more than stair descent ($F(11)= 9.04$, $P= 0.012$, Eta= 0.45). The results showed that the main effect of vision had a significant effect on stance time ($F(22) = 25.8$, $P= 0.0001$, Eta= 0.54). Within the group's results showed that closing the eyes in people with full-sight caused a significant increase in stance time comparing with open eye condition ($F(11)= 25.8$, $P=0.0001$, Eta = 0.70). But the difference between groups in this variable was not significant. The results regarding stride length and step length pointed out that the factor of task did not have a significant effect on stride length and step length ($P > 0.05$). However the factor of vision had a significant effect on stride length ($F(22)= 7.6$, $P= 0.01$, Eta=0.26), but this factor did not affect step length significantly. Furthermore, the factor of group significantly affected stride length ($F(22)= 7.6$, $P= 0.02$, Eta= 0.41)and step length ($F(22)= 9.12$, $P= 0.006$, Eta= 0.29). Stride length and step length were significantly more in group with full-sight comparing with the group with sight loss. The results of comparison between groups showed that stride length in open eye condition and in both stair ascent and descent had a significant difference between 2 groups ($P< 0.05$). Nevertheless, in closed eye condition no differences were obvious between groups ($P> 0.05$). Comparison between the groups regarding step length pointed out that the difference was only significant in stair descent with open eyes ($P= 0.001$) and in other cases the difference between 2 groups was not significant.

Table 2. The mean (SD) of spatiotemporal variables of stair ascent in two groups.

		Full-sight		Sight loss
		Eye open	Eye closed	
Spatial-temporal parameters				
Cadence	Right foot	82.20 (9.21)	47.99 (14.97)	62.63 (8.74)
	Left foot	88.52 (11.42)	48.57 (15.60)	63.62 (12.03)
Speed	Right foot	0.48 (0.06)	0.26 (0.09)	0.31 (0.07)
	Left foot	0.54 (0.08)	0.28 (0.09)	0.33 (0.08)
Temporal parameters				
Stride time	Right foot	1.48 (0.17)	2.75 (0.78)	1.97 (0.33)
	Left foot	1.38 (0.18)	2.86 (1.08)	2.05 (0.59)
Step time	Right foot	0.75 (0.10)	1.49 (0.57)	0.94 (0.18)
	Left foot	0.68 (0.11)	1.49 (0.62)	1.00 (0.34)
Single support time	Right foot	0.48 (0.05)	0.61 (0.12)	0.50 (0.13)
	Left foot	0.49 (0.04)	0.64 (0.12)	0.50 (0.11)
Double support time	Right foot	0.50 (0.10)	1.51 (0.61)	0.97 (0.25)
	Left foot	0.41 (0.09)	1.70 (0.97)	1.05 (0.55)
Swing time	Right foot	0.48 (0.05)	0.61 (0.12)	0.50 (0.13)
	Left foot	0.49 (0.04)	0.64 (0.12)	0.50 (0.11)
Stance time	Right foot	1.22 (0.85)	2.12 (0.65)	1.47 (0.27)
	Left foot	0.91 (0.13)	2.34 (1.06)	1.55 (0.55)
Spatial parameters				
Stride length	Right foot	0.71 (0.03)	0.66 (0.06)	0.59 (0.12)
	Left foot	0.74 (0.05)	0.70 (0.08)	0.63 (0.13)
Step length	Right foot	0.35 (0.04)	0.35 (0.04)	0.32 (0.04)
	Left foot	0.38 (0.06)	0.35 (0.05)	0.33 (0.14)

Table 3. The mean (SD) of spatiotemporal variables of stair ascent in two groups

		Full-sight		Sight loss
		Eye open	Eye closed	
Spatial-temporal parameters				
Cadence	Right foot	91.01 (12.82)	53.43 (14.72)	72.28 (18.19)
	Left foot	90.67 (11.32)	56.74 (16.50)	72.52 (23.42)
Speed	Right foot	0.54 (0.09)	0.29 (0.09)	0.33 (0.09)
	Left foot	0.56 (0.07)	0.30 (0.10)	0.33 (0.10)
Temporal parameters				
Stride time	Right foot	1.35 (0.21)	2.53 (0.70)	1.89 (0.73)
	Left foot	1.35 (0.18)	2.41 (0.76)	1.93 (0.92)
Step time	Right foot	0.68 (0.11)	1.27 (0.41)	1.06 (0.70)
	Left foot	0.66 (0.08)	1.15 (0.30)	0.90 (0.31)
Single support time	Right foot	0.49 (0.09)	0.66 (0.15)	0.55 (0.14)
	Left foot	0.50 (0.08)	0.69 (0.25)	0.52 (0.19)
Double support time	Right foot	0.36 (0.05)	1.12 (0.42)	0.80 (0.84)
	Left foot	0.36 (0.05)	1.09 (0.46)	0.82 (0.85)
Swing time	Right foot	0.49 (0.09)	0.66 (0.15)	0.55 (0.14)
	Left foot	0.50 (0.08)	0.69 (0.25)	0.52 (0.19)
Stance time	Right foot	0.86 (0.12)	1.78 (0.48)	1.36 (0.81)

	Left foot	0.87 (0.11)	1.79 (0.67)	1.35 (0.88)
Spatial parameters				
Stride length	Right foot	0.71 (0.06)	0.67 (0.14)	0.57 (0.16)
	Left foot	0.74 (0.04)	0.66 (0.10)	0.57 (0.15)
Step length	Right foot	0.36 (0.05)	0.37 (0.10)	0.29 (0.13)
	Left foot	0.38 (0.03)	0.35 (0.09)	0.30 (0.06)

Discussion

The present paper is aimed at studying the effect of vision on spatiotemporal variables during stair locomotion in people with full-sight and comparing them with people with sight loss. The results of various studies showed that the decrease in visual input and even visual acuity could increase fall risk while walking. These studies focused on the effect of vision and aging (30,31). Marginal research studying walking in people with sight loss showed that these people used some mechanisms while walking to decrease fall risk, in other words these mechanisms resulted in cautious walking in people with sight loss (32).

Spatiotemporal Parameters

The results of this study showed that the speed of stair ascent in sighted people in open eye condition was approximately 95.5% more than closed eye condition. Moreover, the speed of stair ascent in open eye condition in sighted people was 62.5% more than people with sight loss and in closed eye condition, was approximately 16.7% less than people with sight loss, and this value was not significant. These results were similar in stair ascent and descent. Studying the results on cadence also pointed out that in both visual states and also in group with sight loss cadence in stair ascent was less than that of stair descent, which meant the frequency of gait while stair descent was more than stair ascent. Also the value of cadence in stair ascent in people with full-sight in open eye condition was nearly 77% more comparing with closed eye condition. Comparing 2 groups showed that the cadence in people with full-sight in open eye condition was nearly 35.2% more than people with sight loss and in closed eye condition was approximately 23.5% less than people with sight loss. Comparing cadence in stair descent showed that in people with full-sight in open eye condition it was 25.5% more than people with full-sight and in closed eye condition approximately 31.4% less than people with sight loss. Considering the mentioned results in cases cadence and speed, it can be concluded that omitting visual input in people with full-sight decreased the speed and frequency of gait on stairs. Obviously walking on stairs without visual input could increase fall risk, which could be decreased through declining the speed while gait on the stairs. These results were consistent with the findings pointed out by Mac Gowan (33). They showed that gait speed in people with sight loss is less than people with full-sight. Hallemans et al., (34) also showed that the speed of gait and cadence in people with sight loss was less than people with full-sight and it was consistent with the results of the present study. Nakamura et al, observed less speed of walking in people with sight loss (32).

Temporal parameters

There was not any significant difference in stride time and step time in stair ascent and descent which was the same in both groups. The results on visual inputs pointed out that stride time in stair ascent in people with full-sight in open eye condition was almost 95% and in stair descent it was approximately 83% less than closed eye condition. Comparison between groups showed that stride time in stair ascent in closed eye condition in people with full-sight was approximately 40.2% less than people with sight loss and in open eye condition nearly 39% more than people with sight loss. Comparing stride time in stair descent showed that in people with full-sight in open eye condition it was approximately 42.2% less than people with sight loss and in closed eye condition it was almost 29% more than people with sight loss. These results were almost the same about step time. Regarding the mentioned results, it is worth mentioning that the stride time in people with full-sight after closing eyes became significantly more than people with sight loss, although before this test, these people had experienced the laboratory atmosphere and stair height, still had a longer stair and step time comparing with people with sight loss. Single support time in closed eye condition and while stair ascent raised by almost 28/5% and while stair descent approximately by 36% comparing with open eye

condition in people with full-sight. Comparison between groups showed that single support time was approximately by 26% more than people with sight loss. Double support time in group with full-sight in stair ascent was more than stair descent. Comparing 2 states of open and closed eyes while stair ascent showed that, closing the eyes could increase double support time 3/5 times in people with full-sight and while stair descent almost 3 times comparing with open eye condition. This meant in closed eye condition, the individual had spent more time in double support time before going to the next stair. The results between the groups also indicated that double support time in people with full-sight in open eye condition was approximately 2.2 times less and in closed eye condition almost 1.6 times (60%) more than people with sight loss. However, in stair descent with closed eyes, double support time in people with full-sight was 2/3 times less and in open eye condition 35% more than the group with sight loss. Stance time in people with full-sight in open eye condition and while stair ascent was approximately 42% less and in closed eye one almost 47% more than people with sight loss. Stance time in stair descent with open eyes in people with full-sight was almost 60% less and in closed eye condition approximately 32% more than people with sight loss.
These results also showed the importance of visual input in people with full-sight and could refer to selecting particular motion patterns in people with sight loss. Hallemans et al, consistent with the findings of the present study pointed out that gait speed, stair length and double support time in people with sight loss is less than people with full-sight (34). Nakamura et al, indicated longer stance time in people with sight loss (32). Therefore, according to Hallemans et al, people with full-sight due to reliance on visual input, for preserving the walking pattern in closed eye condition, showed more changes, which was consistent with the results of the present study (6). Various research were conducted on the effect of vision on posture control (6,8,35) which showed that disturbing received information from eyes and blocking vision could increase stride time, but other parameters did not show any significant changes. These results were consistent with the findings of the present study. Therefore it could be concluded closing eyes could affect gait pattern and people with full-sight are dependent on visual input even in a challenge-free condition. The changes in walking with closed eyes in people with full-sight were due to lack of exercise and also inconsistency with these conditions. As a result, different variables; cadence, stride time and step time underwent many changes, so that these changes were even greater than these variables in people with sight loss. Moreover, it is worth mentioning that proprioceptive recipients in people with sight loss had a bigger role for walking control comparing with people with full-sight (36).

Spatio variables

By omitting visual input in people with full-sight, stride length while stair ascent decreased by nearly 8%, but while stair descent, this decrease was approximately 9%. Stride length in people with full-sight, just in open eye condition had a significant difference with people with sight loss, namely stride length in people with full-sight while stair ascent was 20% more than people with sight loss, but it was 28% more in stair descent. Regarding step length the differences were not significant not within the groups nor between them.
These results showed that people with full-sight in both open eye and closed eye conditions had more stride length comparing with that of people with sight loss. The findings of Clark-Carter et al., (37) indicated that people with sight loss had shorter stride length and walked slower. The generalizability of the findings of the study are limited by the small sample size and also lack of the existence of a comparison group which was due to the fact that it was difficult to find a sufficient number of congenitally blind people reflecting the traits of interest to the study. Another limitation which could have affected the generalizability of the findings may be due to the fact that female participants were not represented in the study as there were few of them willing to participate and even those few failed to present their parents' consent letters for taking part in the study.

Conclusion

In the line of previous research, the results of this study showed that blind people were weaker in some of the parameters of stair ascent and descent compared to full-sighted persons in open eyes condition; but the blind people in both stair ascent and descent stairs were better compared to the full-sighted person in close eyes condition .The results are interesting because people with full-sight were familiar with the conditions and environment of the laboratory. Therefore, blind people relying on the other sensory information, had a better performance in stair ascent and descent stairs compared to the full-sighted person in close eyes condition. Whereas performance of full-sight person was impaired after removing their visual information, due to their reliance on visual system information.

Using cane or installing some bars near the stairs might help the people with sight loss to step faster. The results on closed eye condition in people with full-sight showed that through omitting visual input in people with full-sight, spatiotemporal variables in stair ascent and descent aggravated comparing with people with sight loss. Due to the fact that no other research has been conducted in this respect, more studies are required. Identifying the effects of lack of visual input in people with sight loss while stair ascent and descent can be effective for designing novel equipment or rehabilitation programs for improving locomotion pattern (38-45).

Acknowledgments

The authors are thankful to all the participants and their families for their participation in this study.

Conflict of interest

The authors do not have any conflict of interest which could have influenced the results of this study.

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چکیده فارسی

متغیرهای فضایی زمانی بالا و پایین رفتن از پله در افراد با نابینایی مادرزادی و افراد بینا

جمشید نوری غفار[1]، مهدی مجلسی[1]، الهه آزادیان[2]، امیر فتح اللهی[3]

1- *گروه بیومکانیک ورزشی، دانشکده علوم انسانی، دانشگاه آزاد اسلامی، واحد همدان، همدان، ایران.*

2- *گروه رفتار حرکتی، دانشکده علوم انسانی، دانشگاه آزاد اسلامی، واحد همدان، همدان، ایران.*

3- *گروه تربیت بدنی علوم ورزشی، دانشگاه محقق اردبیلی ، اردبیل ، ایران*

بالا و پایین رفتن از پله یک تکلیف پرچالش در افراد نابینا است. هدف از انجام پژوهش حاضر، ارزیابی متغیرهای فضایی زمانی در بالا و پایین رفتن از پله در افراد نابینا و مقایسه آن با افراد با بینایی عادی بود. در این مطالعه متغیرهای فضایی زمانی بالا و پایین رفتن از پله در ۱۲ فرد بینا و نابینا با استفاده از دستگاه تحلیل حرکتی سه‌بعدی Viconبا فرکانس ۱۰۰ هرتز اندازه-گیری شد. برای تجزیه و تحلیل دورن گروهی از آزمون Repeated measure و بین گروهی از آزمون تی تست مستقل در سطح معنی داری p< ۰/۰۵ استفاده شد. نتایج نشان دادند افراد نابینا دارای سرعت، کادنس و طول گام کمتری نسبت به گروه بینا بودند (p< ۰/۰۵). همچنین زمان گام و قدم، زمان اتکای یک پا و دو پا و زمان اتکا در گروه نابینا به طور معنی‌داری بیشتر از گروه بینا بود (p< ۰/۰۵). در متغیرهای کادنس و زمان اتکا اختلاف معنی‌داری بین بالا و پایین آمدن از پله وجود داشت (p< ۰/۰۵)، که در هر دو گروه این اختلاف مشابه بود (p> ۰/۰۵).

کاهش سرعت و کادنس و افزایش در زمان اتکا نشان‌دهنده عدم کارایی در حرکت افراد نابینا می‌باشد. با توجه به این نتایج افراد نابینا دارای الگوی پله روی محتاطانه می‌باشند که در افراد سالم در وضعیت چشم بسته متغیرهای فضایی-زمانی نسبت به افراد نابینا دارای الگوی ضعیف-تری بود.

واژه‌های کلیدی: نابینا، متغیرهای فضایی و زمانی، بالا و پایین آمدن از پله، چشم باز و بسته.