

Electromyographic Patterns of Lower Limb Muscles during Gait in Congenital Blindness and Sighted People

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ABSTRACT

The visual system collects the information of the surroundings of the individual and plays a significant role in taking and maintaining balance and stability and planning the course of the movement. This study aimed to compare muscle activity of gait among blind and persons with full-sight and investigate the effects of closing the eyes on muscle activity of gait in persons with full-sight. In the present study 20 male (blind and persons with full-sight) were participated. Muscle activity of gait was measured in blind subjects without a cane and in normal subjects with and without vision. The differences between the two groups and the two walking conditions were determined through repeated measure ANOVA at a significance level of $P < 0.05$. The results showed that eye closure did not cause a significant change in the activity of the selected muscles. Also, the intensity of activity in the tibialis anterior and gastrocnemius medialis muscles on the right side in open-eye condition was significantly different in persons with full-sight compared to the experimental group in both walking phases. Comparison of the intensity of muscle activity in blind and persons with full-sight in closed-eye condition showed a significant difference of the tibialis anterior and gastrocnemius medialis in the right foot and the biceps femoris in the left foot ($p < 0.05$). The findings imply that blind people have been able to increase their motor efficiency by changing the pattern of gait and using other sensory systems.

Keywords: Gait, Blindness, vision, Muscle activity, Electromyography.

Introduction

Three sensory systems of visual, atrial and somatosensory have roles in maintaining upright standing posture and balance control in gait [1, 2]. If it is presumed that to maintain the posture, we need all information about the sensory systems, the lack of information of one of the sensory systems affects the balance of the body during standing and gait [1]. The visual system collects the information of the surroundings of the individual, such as distance and plays a significant role in taking and maintaining balance and stability and planning the course of the movement [3, 4].

People with visual impairment, specifically in congenitally blind individuals, have never received visual stimuli. In spite of the lack of vision from the beginning, they have learned motor activity and motor skills, such as orientation and motor activities in everyday life. However, their motor patterns may differ from ordinary people [5]. In blind people, the lack of vision input data affects gait patterns [6]. In blind people, walking speed and step lengths are shorter and retention time is longer than the normal [3], and a greater base of support and toes outward [6] prudent posture maintenance state are among the walking features of these people [7]. McGuan indicated that step length, walking speed, stance time, and angle of the joints in the lower extremities of blind children are different from children with full-sight [8]. Majlesi and Farahpour

suggested that lower speed and shorter step length in blind people are probably because of the greater role of somatosensory receptors than normal people [9]. Given the high iteration of a gait cycle in everyday activities, any disorder can have a significant impact on the function of the joints, muscles and the health of the blind people. Although falling can have various reasons, visual impairment is one of the main and important factors among them [10].

Most of the studies conducted on the blind gait are related to research in the kinematics of gait, and no studies have been conducted on recording the activity of the muscles involved in the gait of these patients. In the few studies on the role of vision and muscle activity involved in gait, Spaulding et al. (1995) asked 20 low-vision and 20 persons with full-sight to walk for eight meters.

The study compared the activity of soleus, tibialis anterior, semitendinosus, and rectus femoris muscles in the stance and swing phases of gait. They concluded a difference between the activities of EMG in the stance phase of one leg between the two groups. Overall, the control group's muscle activity was higher than the low vision group [11].

Reduction in the ability to the maintenance of balance is a major problem in blind people [12], weakness in postural control, poor balance, difficulty in gait [13], and vision problems [10] are significant factors for falling and injury in this population.

Identification of all kinetic and kinematic parameters and muscular activity can be effective in identifying the adaptive mechanism of blindness in the blind to compensate for the lack of visual input [14, 15]. Thus, understanding postural adaptability and biomechanical analysis of gait can be effective in developing information on the movement control of blind people. By identifying the pattern of contraction of the muscles in the gait of the blind, can identify the blind people's problems in walking, and this information can be used to improve walking aids and design of motor exercises and rehab [10].

The hypothesis of this study was the lack of visual input in blind subjects resulting in the adoption of specific postural strategies can affect the functioning of the muscles involved in walking. Thus, the researcher is going to examine the electromyography activity of the lower limb muscles in the walking of blind people.

Material and Methods

We used the freeware tool G*Power (<http://www.gpower.hhu.de/>) to calculate an a priori power analysis. 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 previous studies [1]. The analysis revealed that 20 children are sufficient to observe large between-group differences. Therefore, in this cross-sectional study, 10 blind males were selected as experimental group and 10 males with full-sight volunteers as a control group. Subjects in the experimental group were born blind. Individuals of both groups did not have any continuous exercise history in the past two years. People who have had injuries in the lower limbs or neurological diseases (muscle ailments) and orthopedic (bone fracture, tendonitis, sprain, strain, and joint surgery) over the last six months were excluded from the study. An Optometrist for not having sight problems examined control subjects and people with vision problems were excluded from the study. Moreover, the subjects completed the consent form to participate in the test, and then the stages of the tests and measuring the variables and method of work were completely explained to the subjects. The Medical Ethics Committee of Hamadan University of Medical Sciences approved the protocol of this study on January 10, 2015 with 5827/9/35/16/13 number.

A four camera Vicon system (Oxford Metrics, Oxford, UK) was used to record three-dimensional lower-body kinematic data (100 Hz) with the Plug In Gait marker set [2] and a Nexus 1.8.2 software (Oxford Metrics, Oxford, UK) was used to determine the events of gait cycle.

Retro-reflective markers of 14 mm in diameter using bipolar adhesive were connected to anatomical landmark points of each participant's leg. These include the anterior-superior iliac spine, posterior-superior iliac spine, lateral epicondyle of the knee, lower lateral one-third surface to the thigh, lateral malleolus, lower one-third of the shank, over second metatarsal head, and on the calcaneus [2, 3].

In doing so, the cameras were first calibrated in a calibration space of $3 \times 2 \times 1.5$ m. Subjects walked at self-selected speed along a 12-m walkway. The starting place of the gait was determined by trial and error, so that each leg has a complete step inside the calibrated space. The distance from the starting point to the calibrated space was such that, before entering the calibrated space, the subject took at least seven steps [4], and the length of the 12-meter route made it possible after space was calibrated at least about seven steps were taken. With these conditions, the effects of starting and stopping of gait were eliminated. Kinematic data were filtered by zero lag fourth order Butterworth filter with cut-off frequency of 6 Hz.

Data on muscle activity was collected by wireless surface EMG (BTS FREEEMG 300, BTS Bioengineering, Italy). The electrodes were connected to the gastrocnemius medialis, tibialis anterior, vastus lateralis and biceps femoris muscles and procedures for EMG recording were according to SENIAM [5]. For this purpose, first, the hair of skin shaved and the skin was cleaned with 5% isopropyl alcohol. The position of the electrodes was parallel to the muscle fibers.

Muscle activity was monitored throughout all trials, differentially amplified and sampled at 1000 Hz with 14-bit resolution, common rejection mode of 100dB. The raw EMG signals were smoothed with a 4th order band-pass Butterworth digital filter at 10-500 Hz. Surface electrode pairs were positioned at an interelectrode distance of 2 cm.

After calibrating the cameras and installing the markers and electrodes, the subjects walked in a designated path without shoes. Subjects' walking assignments were: a) normal walking for the blind, b) open-eye walking for persons with full-sight, and c) closed-eye walking for persons with full-sight.

The subjects in both groups were asked to walk at the usual walking speed. All the subjects, after the start of the test, routinely warmed up for about 5 minutes and traveled through the path for several times. The blind people also traveled this route several times using their cane. While implementing the main test, blind people were assured that verbally they would be alerted in case of deviation from the route or the likelihood of any collision with the objects. In each of these conditions, walking was repeated nine times, and in each of these variables, an average of 6 repetitions was considered for statistical calculations.

A maximum voluntary isometric contraction (MVIC) of the muscles was used to normalize the data. MVIC iterations were performed in the external wide muscle in the flexion position of 90° of the hip joint and flexion of the knee of 60° and during knee extension in the sitting position (on the front thigh and in the isometric position), and in two muscles in the same previous position of the joint thighs and knees and during the movement of the flexion [6, 7]. MVIC iterations for the tibialis anterior muscle were fully and completely extended at 90° degree angle to the constant resistance of the device and during dorsiflexion [8]. Concerning the gastrocnemius medialis muscle, the position of the plantar flexion in standing position on one leg has been used to normalize the data of this muscle, since it has been proven that there is a greater amount of muscle activity relative to the maximum isometric voluntary contraction [6].

The subjects performed 2 repetitions of MVIC for 5 seconds for each muscle or muscle group and randomly and about one minute rest was assigned for each subject between each repetition. EMG graphing software (Motion Lab Systems, Inc., Tampa, Florida) was used to analyze the electromyography data.

Shapiro–Wilk test was used to examine the normality of the data for the possibility of using parametric tests. The experimental design of this study had two internal factors: a) walking factor with two levels (walking with eyes open and closed eyes), and b) operating side of the body with two levels of the right foot and left foot. Additionally, an intergroup factor with two levels of blind and control group was considered. Given the

research design, in intra-group comparison repeated measure and in inter-group comparison, MANOVA was used. All statistical analysis steps were performed using SPSS with a significant level of $p < 0.05$.

Results

The mean and standard deviation of the characteristics of participants are presented in Table 1. As is seen, persons with full-sight did not have a significant difference in terms of demographic characteristics with blind subjects.

Table 1. Average and standard deviations of subjects' demographic variables in the studied groups

Variables	Experimental	Control	Sig.
Age	24.70±5.50	23.90± 4.90	0.72
Height	1.71±0.50	1.75±0.40	0.10
Mass	61.80±10.70	78.50±7.53	0.09
BMI	23.33±3.80	25.46±2.28	0.15

Note: abbreviations: SD: standard deviation, BMI (Body Mass Index, age in year, height in meters, mass in kilograms).

Comparison of the effect of vision in the control group showed that eye closure did not cause a significant change in the activity of the selected muscles ($F(9,1)=11$, $p=0.74$, $Eta=0.01$) (Fig. 1). Furthermore, the muscle activity in both left and right legs was similar ($F(9,1)=0.03$, $p=0.85$, $Eta=0.004$). However, the level of muscle activity in gait phases was significantly different ($F(9,1)=8.06$, $p=0.019$, $Eta=0.47$). Accordingly, the severity of muscle activity in the two phases of stance and swing had significant differences.

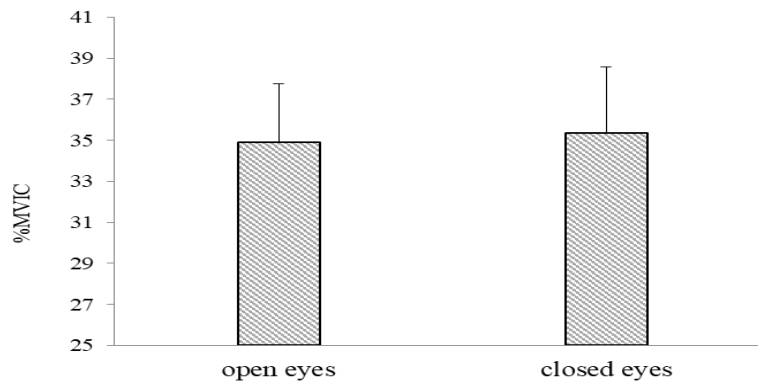


Figure 1. The effect of visual factor on muscle activity in control group

The results showed that the interaction between the two sides of the body and the vision was not significant, meaning that the intensity of muscle activity when walking with open or closed eyes was similar in both left and right foot ($F(9,1)=0.93$, $p=0.35$, $Eta=0.09$).

The interaction of the visual and gait phases factors was not significant. In other words, the activity of the muscles when walking with open or closed eyes was similar in each stance and swing phase ($F(9,1)=2.95$, $p=0.12$, $Eta=0.25$). Furthermore, the interaction between the two sides of the body and the gait phases were not significant, i.e. the activity of the muscles in the two left and right legs were similar in each stance and swing phase ($F(9,1)=0.000$, $p=0.98$, $Eta=0.000$).

The results showed that the interaction between vision and intensity of activity in the four selected muscles was insignificant, so in both open and closed eyes states, the intensity of muscle activity was similar ($Eta = 0.18$, $p = 0.66$), $F(7,3)=0.54$) (Fig. 2).

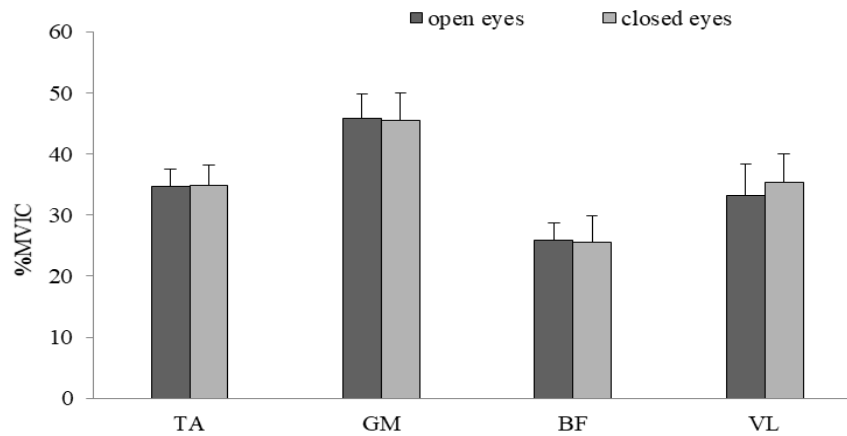


Figure 2. The effect of visual interaction and intensity of muscle activity in the experimental group
 Note: abbreviations: TA: Tibialis anterior, GM: gastrocnemius medialis, BF: Biceps femoris, VL: Vastus lateralis.

Comparison of muscle activity in blind and persons with full-sight in the open-eye state showed that the intensity of activity in the tibialis anterior and gastrocnemius medialis muscles on the right side and in both walking phases was significantly different in persons with full-sight compared to the experimental group. Moreover, comparing the intensity of muscle activity in the left foot showed that biceps femoris muscle in two phases of swing and stance had a significant difference in the two groups ($p < 0.05$).

Comparison of the intensity of muscle activity in blind and persons with full-sight in the closed-eye state showed a significant difference in the right foot of the tibialis anterior and gastrocnemius medialis and in the left foot of the biceps femoris muscle in swing and stance phases with the experimental group ($p < 0.05$).

Discussion

The aim of this study was to examine the role of visual input on muscle activity in walking of blind and persons with full-sight. The results showed that closing the eye had no significant effects on the intensity of muscle activity in the control group. However, the intensity of the activity of the selected muscles in the stance and swing phase of the gait was significant. In the stance phase, the intensity of activity was significantly higher in the biceps femoris and gastrocnemius medialis. In the swing phase, the intensity of activity was higher in tibialis Anterior and Biceps femoris muscles.

Comparison of the groups showed that the intensity of tibialis anterior, biceps femoris and gastrocnemius medialis muscles activity in persons with full-sight was more in swing phase compared to the experimental group, but in the stance phase, biceps femoris muscle has a higher intensity of contraction in the control group compared to the blind. These results were similar in both open and close eye states compared to the experimental group. The results showed that the intensity of the contraction of muscles in stance and swing phases was similar among the two groups.

Comparing the results of this study with the study by Nakata et al. (1990) showed that, in contrast to the present study, visually impaired people had a similar muscle activity pattern to that of persons with full-sight in the closed-eye state [9]. The study by Spaulding et al. showed that muscle activity in the control group was significantly higher than the low vision group [10].

Furthermore, Majlisi and Farahpour (2016) showed that walking speed in control people in open eyes was significantly higher than that of blind subjects and there were no significant differences in closed eye condition [11]. Many studies have shown that blind people have low walking speeds, short step length, and longer stance times. These changes in gait may reflect the strategies that blind people have taken to maintain

posture stability [12]. Studies have suggested that blindness may lead to increased accuracy in the quality of the remaining senses to a degree that compensates for lost vision [13, 14].

Hence, considering that walking speed is lower in blind subjects than in persons with full-sight in open-eye conditions, low activity of muscles during walking is predictable in blind subjects. However, as the walking speed of persons with full-sight in closed-eye condition did not show a significant difference with the experimental group, and on the other hand, the intensity of muscle activity in the experimental group was lower than persons with full-sight, one can conclude that deprivation of vision in these individuals has led to the development of strategies that increase motor performance in blind people.

Motion performances in blind people are exclusively related to sensory information provided by other senses other than vision, such as tactile, proprioceptive system, vestibular, and these senses develop in both muscle activity and motor coordination. These people control their posture with the remaining senses [9]. Posture control systems in blind people may be more unstable compared to sighted people, but over time, they create the necessary performance to deal with the environment [15-19].

Walking with normal and desired speed leads to the emergence of predominant and practiced strategies in blind people, whereas walking with closed-eyes in persons with full-sight needs to search and adapt to a new situation, which results in reduced efficiency in them. Hence, it seems that to examine the difference in walking ability between blind and persons with full-sight, we should examine the walking pattern at different speeds and situations.

Conclusion

The results showed that the elimination of visual inputs did not make significant changes in the intensity of the activity of the selected muscles. However, the inter-group comparison showed that in closed and open-eyed conditions in persons with full-sight, the intensity of muscle activity was higher than that of blind subjects. Thus, the findings imply that blind people have been able to increase their motor efficiency by changing the pattern of gait and using other sensory systems.

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چکیده فارسی

الگوی الکترومیوگرافی عضلات اندام تحتانی در هنگام راه رفتن در افراد نابینای مادرزاد و افراد بینا

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چکیده فارسی

سیستم بینایی اطلاعات محیط اطراف فرد را جمع‌آوری کرده و در حفظ تعادل و ثبات و برنامه‌ریزی مسیر حرکت نقش بسزایی دارد. این مطالعه با هدف مقایسه فعالیت عضلات در راه رفتن نابینایان و افراد با بینایی عادی و بررسی تأثیر بستن چشم بر فعالیت عضلات راه رفتن در افراد با بینایی عادی انجام شد. در مطالعه حاضر ۲۰ مرد (نابینا و افراد با دید کامل) شرکت کردند. فعالیت عضلات راه رفتن در افراد نابینا بدون عصا و در افراد عادی با و بدون بینایی اندازه‌گیری شد. اختلاف بین دو گروه و دو وضعیت گام‌برداری از طریق آزمون ANOVA ویژه داده‌های تکراری در سطح معنی‌داری $p < 0/05$ تعیین شد. نتایج نشان داد که بستن چشم باعث تغییر معنی‌داری در فعالیت عضلات انتخابی نشده است. همچنین شدت فعالیت عضلات ساقی قدامی و دوقلوی داخلی در سمت راست در شرایط چشم باز در افراد دارای دید کامل نسبت به گروه نابینا در هر دو مرحله گام‌برداری تفاوت معنی‌داری داشت. مقایسه شدت فعالیت عضلات در افراد نابینا و افراد با دید عادی در وضعیت بسته چشم، تفاوت معنی‌داری در عضلات ساقی قدامی و دوقلوی داخلی در پای راست و راست رانی در پای چپ را نشان داد ($p < 0/05$). این یافته‌ها حاکی از آن است که افراد نابینا با تغییر الگوی راه رفتن و استفاده از سایر سیستم‌های حسی توانسته‌اند بازده حرکتی خود را افزایش دهند.

واژه‌های کلیدی: گام‌برداری، نابینایی، بینایی، فعالیت عضلات، الکترومیوگرافی.