Research Paper: sEMG Characteristics of the Lower Extremity Muscles During Walking in Mentally Retarded Adolescents

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ABSTRACT

Purpose: Less attention has been paid to the electromyographic activity of the lower extremity muscles, which is considered as an essential part of the kinetic studies on the gait of mentally retarded individuals. Hence, the study aims at determining the surface electromyography characteristics of the lower extremity muscles of mentally retarded adolescents during walking.

Methods: It is a causal-comparative study. Fifteen mentally retarded and 15 normal adolescents with an age range of 10 to 14 years participated in this study. To record the activities of vastus medialis, vastus lateralis, biceps femoris, semi-tendinosus, tibialis anterior, long peroneal, medial gastrocnemius, and soleus muscles, sEMG was employed during the stance phase of gait. For the data analysis, an independent sample t-test was conducted using SPSS version 18.

Results: The results revealed that the mentally retarded adolescents had higher level of biceps femoris muscle activity in the heel contact sub-phase (P=0.016) compared to the normal group. Also, the vastus medialis (P=0.015) and the long peroneal (P=0.026) muscles showed higher EMG activity. Furthermore, their vastus lateralis (P=0.039) and Soleus (P=0.002), and vastus medialis (P=0.045) muscles demonstrated higher and lower activities, respectively. The co-contraction rate of medial gastrocnemius and anterior tibialis muscles during the heel contact was higher (P=0.040) in individuals with mental retardation compared to the healthy group. **Conclusion:** It can be concluded that the mentally retarded individuals use different muscle activation patterns in comparison to healthy people. As a result, special attention should be given to the functioning of their lower extremity muscles during the corrective power exercises.

Keywords:
Mentally retarded, Walking, Electromyography, Lower extremity, Co-contraction

1. Introduction

Disability is a natural and social phenomenon that can affect different communities in different ways. Some of its common manifestations include lack of independence in life and physical inactivity, resulting in the development of physical and motor weaknesses, such as poor balance and difficulty in walking independently [1]. Hence, mental retardation shows the significant limitation in an individual's adaptive performance, which includes a below average performance (IQ of 70 or below) accompanied

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with limited skills in the field of environmental compatibility [1]. According to the available statistics, about 3% of the world's population has an IQ of less than 68, among which over 80% are educable [2].

Mobility is one of the main aspects of life, and walking as a basic human skill and the original way of a child's movement and relocation, has appropriated the daily motor activity of humans [3, 4]. Due to the special mental conditions and the resulting social problems, the mentally retarded people are more immobile with less physical activities compared to the healthy people, which results in physical and motor weaknesses [1, 2]. Physical inactivity leads to reduced voluntary power and capacity of muscle function, impaired simultaneous activation of agonist and antagonist muscles, and ultimately lowered performance and efficiency of the neuromuscular system [3, 4]. Specifically, children with mental problems and abnormalities act slower than their normal peers in initiation and implementation of targeted exercises and movement's reaction time [3, 4].

Previous studies have shown that the mentally retarded children usually have poor body conditions with low physical vitality [5]. Enkelaar et al. (2012) stated that the mentally retarded people are involved in unbalanced and unstable ways of walking, indicating their overall weak coordination [5]. In a review of literature related to gait analysis in people with mental retardation highlighted the existence of biomechanical weaknesses that can be associated with high risk of falling. For example, in a biomechanical analysis of mentally retarded adults' gaits conducted by Haynes et al. it was shown that these people have less stride lengths than the normal individuals. In addition, they have further stride widths for balancing for slower walking speed, while their probabilities of sliding from side to side are more than the normal people [6, 7].

The high prevalence of mental retardation, the role of walking as a factor of communication with the environment, and enhancement of muscle performance, despite some kinetic and kinematic studies on their gaits, less attention has been paid to the assessment of lower extremity muscle activity. A study on the muscular behavior of mentally retarded individuals during walking leads to better understanding of the kinetics and helps in determining specific exercise programs that can improve their walking abilities and independence level. Therefore, the aim of this study was to assess the surface electromyography (sEMG) characteristics of some selected lower extremity muscles during walking in mentally retarded adolescents compared to the healthy subjects.

2. Materials and Methods

Fifteen students with mental retardation and 15 normal subjects, aged from 10 to 14 years participated in this causal-comparative study. The mentally retarded subjects were randomly selected from primary and secondary exceptional schools of Hamedan city in 2014. The sample size was determined based on the previous similar studies. The inclusion criteria included an IQ of 50 to 70, not having 2 disabilities along with Down syndrome, no history of surgical operation and injuries or burning in the lower extremity, no mutilation, and absence of any cardiovascular problems. After obtaining the permission of their parents and medical records at the school, the students in the afflicted group were selected from special schools of Hamadan City. The research council of Bu Ali Sina University, in agreement with the Declaration of Helsinki, approved all the procedures before the beginning of the study.

After the anthropometric measurements, certain selected areas of the skin, such as vastus medialis (VM], vastus lateralis (VL), biceps femoris (BF), semi-tendinosus (ST), tibialis anterior (TA), long peroneal (LP), medial gastrocnemius (MG), and soleus muscles, were connected to the electrodes according to SENIAM (European Recommendations for Surface Electromyography) instructions [8]. The collected data were normalized to their Maximum Voluntary Isometric Contractions (MVICs) that were obtained from the muscles.

For the BF and ST MVIC, the subjects were seated on the examination table, and their knee and hip were flexed at 90°. The subject was instructed to maximally flex the knee against the manual resistance of the investigator. For the VM, VL and RF MVIC, the maximum isometric knee extension was performed with the hip at 90º and the knee at 60º of flexion. MVIC of PL was performed against the manual resistance of the investigator while the subject was in a sitting position attempting ankle eversion and plantar flexion. For TA MVIC, the subjects exerted a maximal voluntary isometric contraction during ankle dorsiflexion. Soleus MVIC was collected with the subject in a quadruped position with knee and hips flexed to 90 degrees on the table and strapped around the metatarsal heads. MG MVIC was collected with the subject lying prone with the test limb off the end of the table and the strap across the metatarsal heads.

To determine the key points of the walking phases, two-foot switches were attached under the most posterior part of the lateral heel and the great toe. Electromyography data were recorded by a 16 channel EMG system (Biomonitor ME6000 T16, Mega Electronics Ltd., Kuopio, Finland).

After attachment of the electrodes and foot switches, the familiarity, and compatibility of the instruments were checked based on the lab conditions. The subjects walked along a 17 m walkway for six times at self-selected speed, and their muscle activities were recorded at the same time. The sampling rate of EMG muscle activity was set at 2000 Hz with the common signal rejection ratio of 110 dB in the differential amplifier. The data were analyzed based on the signal quality of foot switch from the 3rd stride in each trial.

For EMG data analysis, Megawin software, version 3.1 was used. To refine the data obtained from EMG, a band-pass filter of 10 to 450 Hz was employed. To normalize the data, the maximum value of Root Mean Square (RMS) amplitude for each muscle during each stride was considered, and the average RMS muscle activity was expressed in terms of percentage with relation to the maximum activity during MVIC [9]. Ultimately, the different gait phases were analyzed based on the heel contact, mid-stance, propulsion sub-phases, and total stance phase.

To obtain the co-contraction index, the following equation was used [17]:

$$\text{Co-contraction}=\frac{\text{Antagonist muscle activity} \times 2}{\text{Antagonist \& antantagonist muscle activities}} \times 100$$

The co-contraction of agonist and antagonist muscles around the joint is of high biomechanical importance to maintain joint position and stability. Co-contraction values were calculated and analyzed for the muscles around the knee and calf in the anterior-posterior or medial-lateral directions during heel contact, mid-stance, propulsion, and total stance.

The normal distribution of the data was evaluated using Shapiro-Wilk test. The assumption of homogeneity of variance was tested using Levene's Test of Equality of Variances (P>0.05). To compare the study parameters, an independent t-test was used at a significance level of α=0.05. All the statistical analyses were performed using SPSS software, version 18.

3. Results

The demographic information of the present participants of each group is shown in Table 1. The subjects of both the groups had no differences based on demographic size. Table 2 presents the muscle activities of both mentally retarded and healthy groups during the heel contact, mid-stance and propulsion sub-phase, and total stance phase.

As it can be seen, the biceps femoris activity of the mentally retarded subjects was significantly higher than the healthy group during the heel contact sub-phase (P=0.003). During mid-stance sub-phase, the vastus medialis (P=0.015) and long peroneal (P=0.026) muscles had higher activities in people with mental retardation in comparison with the healthy group. A comparison of the activities of the lower extremity muscles in the propulsion sub-phase showed higher activities of vastus lateralis (P=0.035) and soleus (P=0.002) muscles, and lower activity of the vastus medialis (P=0.045) muscle in mental retardation group.

There were differences in muscle activities of the two groups during the whole stance phase of gait. According to the results, vastus lateralis (P=0.018), biceps femoris (P=0.001), and long peroneal (P=0.011) muscles demonstrated higher activities in the subjects with mental retardation.

Comparison of co-contraction activity between muscles around the knee and ankle joints during heel contact, mid-stance and propulsion sub-phases, and total stance phase of gait in both the study groups are presented in Table 3. The co-contraction rate of medial gastrocnemius and anterior tibialis muscles in individuals with mental retardation during heel contact sub-phase was higher (P=0.040) compared to the healthy group. How-

Table 1. Descriptive statistics of demographic variables.

Variables	Group		P
	Patients	Healthy Subjects	
Age (years)	11.89±1.2	11.96±1.6	0.672
Height (cm)	147.31±4.62	150.37±5.43	0.385
Weight (kg)	36.78±3.51	38.33±4.27	0.324
BMI	16.02	16.72	0.574

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Table 2. Comparison of the EMG activity of muscles (MVIC%) during the stance phase of gait in the study groups (Mean±SD).

Phases	Muscles	Groups		t	P
		Healthy	Patients		
	Vastus lateralis	16.860±7.3	20.855±6.0	-1.635	0.113
	Vastus medialis	20.272±9.3	18.479±4.8	0.662	0.514
	Biceps femoris	14.118±6.9	20.745±7.3	-2.555	0.003
Heel contact	Semi-tendinosus	10.349±8.7	15.149±10.5	-1.362	0.184
	Tibialis anterior	17.956±7.9	13.400±6.7	1.697	0.101
	Long peroneal	14.850±7.9	19.847±6.0	-1.951	0.061
	Medial gastrocnemius	12.355±6.2	13.640±8.1	-0.490	0.628
	Soleus	17.331±8.7	18.444±7.1	-0.385	0.703
	Vastus lateralis	10.836±7.8	14.973±6.4	-1.590	0.123
	Vastus medialis	14.751±7.2	21.152±6.2	-2.596	0.015
	Biceps femoris	11.145±10.2	16.557±9.0	-1.539	0.135
Mid-stance	Semi-tendinosus	8.381±5.4	9.604±5.7	-0.605	0.550
	Tibialis anterior	7.752±6.1	7.742±3.8	0.005	0.996
	Long peroneal	18.553±7.5	25.618±9.0	-2.345	0.026*
	Medial gastrocnemius	17.868±5.0	18.236±5.0	-0.201	0.842
	Soleus	26.825±6.8	31.310±11.7	-1.285	0.209
	Vastus lateralis	6.633±3.5	11.311±7.5	-2.220	0.035*
	Vastus medialis	13.311±5.8	9.545±3.9	2.097	0.045*
	Biceps femoris	5.878±4.3	7.636±5.2	-1.003	0.325
Propulsion	Semi-tendinosus	4.633±2.9	5.268±3.2	-0.571	0.573
	Tibialis anterior	10.776±4.5	12.709±5.1	-1.106	0.287
	Long peroneal	16.324±5.8	20.119±4.9	-1.926	0.084
	Medial gastrocnemius	10.601±3.5	12.247±7.6	-0.764	0.451
	Soleus	13.354±4.8	19.539±5.1	-3.415	0.002*
	Vastus lateralis	11.656±5.8	16.360±4.4.	-2.507	0.018*
	Vastus medialis	15.958±5.7	15.915±4.4	0.023	0.982
	Biceps femoris	9.312±5.9	18.393±7.5	-3.682	0.001*
Total stance	Semi-tendinosus	8.466±4.8	11.367±5.9	-1.486	0.148
	Tibialis anterior	9.490±3.5	10.701±3.9	-0.895	0.378
	Long peroneal	15.155±4.9	21.122±6.9	-2.742	0.011*
	Medial gastrocnemius	15.010±4.7	16.141±5.7	-0.590	0.560
	Soleus	21.008±4.6	25.286±8.8	-1.675	0.105

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Abbreviations: NS stands for No Significant; MVIC stands for Maximum Voluntary Isometric Contractions.

*P<0.05.

Table 3. Comparison of co-contraction activity between the knee and ankle muscles (MVIC%) during the stance phase of gait in the study groups (Mean±SD).

Muscles	Phases	Groups: Healthy	Groups: Patients	t	P
TA and MG	Heel contact	66.923±18.9	82.693±21.2	-2.150	0.040
	Mid-stance	57.401±24.6	59.332±24.7	-0.214	0.832
	Propulsion	100.246±25.4	106.286±44.2	-0.458	0.650
	Total stance	77.857±22.2	81.628±27.7	-0.411	0.684
	Heel contact	68.535±19.6	78.935±14.1	-1.667	0.107
	Mid-stance	61.082±20.7	69.670±14	-1.331	0.194
Q and H	Propulsion	68.010±33.3	78.525±18.8	-1.065	0.296
	Total stance	76.494±28.9	93.577±16.7	-1.980	0.058
	Heel contact	86.625±11.2	79.155±24.1	1.089	0.285
	Mid-stance	59.096±29.9	48.191±23.4	1.113	0.275
TA and LP	Propulsion	80.981±25.4	75.708±22.2	0.605	0.550
	Total stance	78.031±28.4	68.812±23.2	0.975	0.338

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Abbreviations: TA stands for Tibialis Anterior; MG stands for Medial Gastrocnemius; LP stands for Long Peroneal; Q stands for Quadriceps; H stands for Hamestring muscles; NS stands for No Significance.

ever, no significant differences were found between the two groups during any other sub-phases. Co-contraction rates of hamstring and quadriceps muscles of knee joint showed no significant differences. Similarly, there was no significant difference found between long peroneal and anterior tibialis muscles of the ankle joint during sub-phases of the stance phase of walking.

4. Discussion

The purpose of this study was to compare the activity of the lower extremity muscles of mentally retarded adolescents and their healthy peers while walking. The results demonstrated that during the heel contact sub-phase, the biceps femoris muscle had greater activity in individuals with mental retardation. In the mid-stance sub-phase, the vastus medialis and long peroneal muscles showed higher activities in mentally retarded subjects. In the propulsion sub-phase, vastus lateralis and soleus muscles of those with mental retardation were more active, while their vastus medialis muscles showed less activity. Also, in the stance phase, their vastus lateralis, biceps femoris, and soleus muscles showed higher activities. In addition, medial gastrocnemius and tibialis anterior co-contraction rates were higher in the mentally retarded group during heel contact sub-phase as compared to the healthy individuals.

During the heel contact sub-phase, the mentally retarded persons' biceps femoris muscles displayed more activities. A study by Haines et al. (2012) showed that the mentally retarded individuals were involved in greater joint flexion during heel contact when walking [6, 7, 11], which was in line with the results of the present study. Therefore, the additional flexion during heel contact is caused by the greater activity of biceps femoris muscle in people with mental retardation. In the mid-stance sub-phase, the vastus medialis and long peroneal muscle activities were found to be higher in mentally retarded participants. Previous studies have shown that mentally retarded individuals with Down syndrome have more flexion in their knees in the mid-stance sub-phase [11-14].

Winter (1983), reported that more knee flexion indicates walking inefficiency, causing an increase in bone-on-bone forces [15]. To avoid and overcome such inefficiency, more knee extensor muscles strengthening activities needs to be performed [15]. Thus, the vastus medialis muscles of people with mental retardation perform more activities to overcome extra knee flexion and reduce walking inefficiencies. In a study by Fournier et al. (2010) showed that the pressure on the interior part of the foot is greater in mentally retarded people during walking [16]. Murley et al. (2009) reported that further activity of long peroneal muscle increases the load on the medial zone of the foot [17]. Therefore, in case of higher pressure on the internal part of the leg in people with mental retardation, it can be concluded that the enhanced long peroneal muscle activity leads to an increased pressure on the leg interior part, and lead to plantar injuries and bone problems, especially those of the plantar-toe joint over time [16].

The study results revealed that soleus muscle activity in people with mental retardation is greater in the propulsion phase. In a study by Cioni et al. (2001) showed that the flexor plantar torque is lower in such people in the propulsion sub-phase compared to the healthy ones [7]. Therefore, further soleus muscle activities need to be done to compensate for the weak plantar flexion within the mentioned sub-phase.

A review study by Enkelaar et al. (2012) concluded that people with mental retardation have more flexion in their lower extremity joints during the stance phase of gait, and this could be a risk factor for frequent falls [5, 6]. During the current investigation, vastus lateralis, biceps femoris, and long peroneal muscles of the mentioned subjects displayed higher activities during the entire stance phase. It seems that the difference in muscle activity between the two groups, which was observed in this study, can be the cause of kinetic and kinematic changes reported in the previous research [5, 6].

In terms of biomechanics, the co-contraction of agonist and antagonist muscles around the joint is of great importance to maintain the joint stability [18]. The concurrent muscle activity around the joint is called co-contraction that is of the two general and directed types, the latter of which provides joint stability [18]. In the joints where there is an articular laxity and instability, the agonist and antagonist muscles coordinate to produce joint stiffness through co-contraction [19]. In this study, a greater co-contraction was observed in the knee joints of mentally retarded subjects during the swing phase. Further co-contraction could be associated with more lower-limb rigidity [9].

Gontijo et al. (2008) stated that people with mental retardation have a ligamentous laxity and stiffness in their lower extremity joints during the swing and heel contact phases of gait [8]. More laxity in the knee joint during swing phase leads to a skid, imbalance, and risk of falling while walking [10]. It seems that the nervous systems of mentally retarded persons use a more co-contraction rate strategy to compensate for and overcome the further knee joint laxity during the swing phase [9].

Additionally, within the heel contact sub-phase, the co-contraction rate of ankle joint was found to be higher for people with mental retardation compared to the healthy subjects, which could also be due to the ligamentous laxity and lower joint stiffness [9]. The World Health Organization has mentioned brain inefficiency, balance (vestibular, visual, and sensory) systems, and living conditions as the three main mechanisms that reduce the mobility of people with mental retardation. Moreover, their lower IQs cause different patterns of muscle recruitment during the performance of daily activities [2, 9].

Our results provide objective evidence of differences in muscle activation patterns during gait between the mentally retarded individuals and healthy people. These results would be helpful to the therapists and persons involved in the care of these children with special needs. As a result, special attention should be given to their lower extremity muscles during their corrective power exercises.

An important limitation of this study was the lack of kinematic and kinetic variables related to the gait analysis. For instance, gait analysis necessitates identification of heel-strike and toe-off to define the enhanced key components of the gait cycle. This is most accurately quantified using force platforms where a threshold is defined to determine heel-strike and toe-off. Future investigations using more sophisticated techniques, such as the use of force platform, may be of benefit to further understand the strategies used by the mentally retarded adolescents for walking.

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Conflict of Interest

The authors declared no conflict of interests.

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