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Electromyographic Analysis of Ankle Muscles in Young Adults with Down Syndrome Before and After the Implementation of a Physical Activity Program Based on Dance

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ABSTRACT

Introduction: People with Down syndrome have difficulties in postural control and exhibit differences in the displacement of their centre of pressure and in muscle activity compared with the general population. Previous research has shown that centre of pressure displacement is less depending on visual conditions in people with Down syndrome, although improved balance has been observed following specific physical activities based on dance. The aim of the project was to assess the effect of a dance-based physical activity programme on muscle activity in young adults with Down syndrome.

Material and methods: Eleven participants with Down syndrome and eleven participants without Down syndrome as the control group followed an 18-week dance programme. Surface electromyography was used to assess ankle muscle activity before and after completion of the programme in open and closed eyes conditions.

Results: We observed a higher level of muscle activation in Down syndrome group. They showed minor differences between different visual conditions than control group. No significant differences were seen in pre- and post-training in Down syndrome group. Nevertheless, less differences were observed between both groups after training than before.

Conclusions: Although no significant differences were observed in Down syndrome group after training, differences between groups were decreased. These could be related to some postural adaptations. In the future, it will be interesting to increase the sample and also analyse the position of centre of pressure in relation to feet.

Key words: Electromyography, postural control, Down syndrome, standing position, dance.

RESUM

Introducció: Les persones amb síndrome de Down tenen dificultats en el control postural, i mostren diferències en el desplaçament del seu centre de pressió i en l'activitat muscular, en comparació amb la població general. En estudis previs, s'ha vist que el desplaçament del seu centre de pressió és menys depenent de la visió. El seu equilibri millora després de l'aplicació d'activitats físiques específiques. L'objectiu va ser avaluar l'efecte d'un programa de dansa sobre l'activitat muscular en adults joves amb síndrome de Down.

Material i mètode: Onze participants amb síndrome de Down i onze participants sense síndrome de Down, com a grup control, van seguir un programa de dansa de 18 setmanes. Es va avaluar electromiogràficament la musculatura del turmell, abans i després del programa, en condicions d'ulls oberts i tancats.

Resultats: Es va observar un major nivell d'activació muscular en el grup amb síndrome de Down. En aquest grup, les diferències segons la condició visual eren menors que el grup control. No es van observar diferències significatives en el grup amb síndrome de Down després de l'entrenament. No obstant , es van observar menys diferències entre els

dos grups després de l'entrenament que abans.

Conclusions: Tot i que no es van observar diferències significatives en les persones amb síndrome de Down després de l'entrenament, si que van disminuir les diferències entre els grups. Això podria estar relacionat amb algunes adaptacions posturals. En el futur, serà interessant augmentar la mostra i també analitzar la posició del centre de pressió en relació a la base de sustentació.

Paraules Claus: Electromiografia, control postural, sindrome de Down, bipedestació, dansa.

Introduction

People with Down syndrome (DS) often have joint laxity and low muscle tone[1,2]. Motor development and motor reactions are slow, making it more difficult to adapt to the environment during the execution of various motor tasks[3] because of difficulty when controlling postural adjustments[4,5,6]. Researchers have also found differences between people with and without DS when analysing centre of pressure (COP) In general, DS subjects showed higher values for the COP displacements than control subjects (rootmeansquare; mean velocity; sway area and rotational frequency), except for RMS with closed eyes. [7] Also, when comparing the static standing balance between adolescents with and without DS, it was observed that the values for the anterior-posterior, medial-lateral, sway path and velocity of the COP with OE and CE in the DS group were higher, except for the medial-lateral displacement of the COP with closed eyes [8].

Most authors agree that people with DS have reduced ability to maintain stable posture compared to those without DS[9,10]. The reasons for decreased postural stability and balance in people with DS are not yet clear. Some authors suggest that the lack of postural control in groups of people with intellectual disabilities (ID) is related to the coexistence of vestibular anomalies [7], slow response [5,11] and sensory impairment [12,13]. We must take into account that an important part of the people with DS also has an ID coexisting with some of these associated factors.

In previous studies comparing different visual conditions, the authors of this study have observed that young people with DS show a poor postural control in standing position.

Differences with control group (CG) were more evident in opened eyes than in closed eyes condition. When changing conditions, control group increased their anteroposterior displacement in closed eyes versus opened eyes, but SD group didn't do it [14]. Other authors have similarly suggested that people with DS use their muscles differently in dynamic conditions such as walking. Toddlers with DS showed significantly wider step width

than their peers without DS. Toddlers with DS improved the rhythmicity of their muscle burst, sustaining longer bursts but timing remained inconsistent. Decreased inter-burst interval and increased muscle burst duration in toddlers with DS may assist in leg control via stabilizing their lax joints[15]. No group differences (DS vs TD children) on stiffness or on lower limb's co-contraction indices (CCI's) during stance phase were observed but children with DS showed greater CCI during swing[16]. In static conditions such as maintaining a standing position, some authors observed higher muscular activity in adults with DS versus CG. Adults with DS might perform preprogrammed contractions to increase joint resistance and compensate for inherent joint instability occurring for quick and unpredictable perturbations[17.] Responses in children with Down syndrome showed no adaptive attenuation to changing task conditions. Onset latencies of responses in children with Down syndrome were significantly slower than in normal children. Presence of the monosynaptic reflex during platform perturbations at normal latencies suggests that balance problems in children with Down syndrome do not result from hypotonia, which researchers have defined as decreased segmental moto-neuron pool excitability and pathology of stretch reflex mechanisms, but rather result from defects within higher level postural mechanisms [18]. Some studies have shown that there is an increased co-activation of the agonist and antagonist muscle groups, and that could be a security strategy to stabilise the ankle joint and COP, and avoid instability[4,18,19,20]. A higher degree of stiffness is also seen at the ankle[21,22].

Some authors suggest that people with DS can improve their balance with systematic and well-designed training programmes. The adaptation to a 12-week training program resulted in the improvement of the dynamic balance ability of the experimental group (young adults with DS) assessed by a balance deck. Also, they found improvements in muscular strength and muscular endurance for the lower limbs of the participants included in the experimental group[23].

For people with DS, we also know that physical activity (PA) has beneficial effects, improving body mass index (BMI) as well as strength and physical condition[6,24]. Some PA programmes have also been shown to be effective in improving biomechanical parameters during the acquisition of walking at early ages[25,26].

For balance-related benefits, some activities may be more suitable than others. We know that dancers without DS exhibit better postural control than the general population[27], higher levels of proprioception at the ankle, better static equilibrium for head and neck movements, and a lower degree of induced vertigo and nystagmus[28,29]. In dancers, a decrease in osteotendinous reflexes has been observed[30], in addition to a faster response during long latency neuromuscular responses and better muscle activation in situations of imbalance[31].

Regarding management strategies and sensory information, professional ballet dancers are more dependent on somatosensory information and use more proprioceptive input to maintain balance[32,33]. During balance perturbations with the opened eyes, they respond better than the general population[28]. In addition to ballet, there are many other styles of dance. Social dance generates improvements in balance, motor control, postural reactions, and some gait parameters in both the general and elderly population[34,35,36,37]

However, to our knowledge, there are no studies evaluating the influence of dance-based PA programmes on the stabilising muscles of the ankle in people with DS. Therefore, the objective of this study was to determine the effects of a dance-based PA programme on postural control strategies, particularly, the role of the stabilising muscles of the ankle, in young adults with DS compared with those without DS.

Materials and Methods

Participants

Convenience sampling was used to select participants with DS from a special education school. The control group (CG) was recruited from a university in Barcelona, Spain. Twelve young adults with DS and 12 young adults without DS agreed to participate. Both groups were aged between 17 and 22 years. The inclusion criteria for the DS group were a level of ID between 30% and 59%, which implies an Intellectual Quotient percentile (IQ) of 33% to 70%. The ID classification was obtained from patient medical files and represents a combination of level of intelligence and adaptive behaviour. The National Government classifies the percentage of disability (physical, intellectual and/or sensory) in 5 degrees, as follows: non-existent (0%), low (1-29%), moderate (30-59%), severe (60-74%), and very severe (> 75%). Classification is based on items such as the ability to adapt to different daily life environments (professional, cultural, family, or social) and the (IQ), among others [38]. According to the Government, our participants had moderate ID.

The exclusion criteria for the DS group were: mobility problems, standing difficulty, vestibular or neuromuscular disease, and any additional psychiatric diagnoses requiring drug therapy. Identical criteria were applied to the CG group, except those related to intellectual impairment and disability.

Initially, 12 volunteers with DS and 12 without DS enrolled in the study, but one volunteer with DS dropped out due to surgery, and one volunteer from the CG moved out of the area.

All participants and their parents/guardians provided informed consent to participate in the study. A medical examination was performed prior to the initial study assessments in order to rule out possible contraindications to PA.

The study protocol followed the criteria of the Declaration of Helsinki[39] and was approved

by the Ethics Committee.

Procedures

Evaluations were performed at the beginning (pre) and at the end (post) of the 18-week PA programme.

a) Medical history and anthropometric assessment

The following data were recorded: medical and surgical history, foot morphology, posture, body fat percentage, and other descriptive data (age, gender, height, weight, BMI).

Standards, measures, and recommendations of the International Society for Progress in Cineantropometría[40] were used for anthropometric assessment. Subjects were measured barefoot and lightly dressed. Weight was measured on a 0.1 kg precision scale and height with a 0.1 cm precision rod (CAM base, Manrique Hnos. SRL, Buenos Aires, Argentina). BMI was calculated by dividing weight (kg) by height squared (m^2). Waist and hip circumference (Sanny anthropometric tape, Saõ Paulo, Brazil) were also evaluated and the waist/hip ratio (WHR) was determined.

b) Electromyographic (EMG) assessment

The lateral and medial gastrocnemius, anterior tibialis, and soleus were studied bilaterally with an electromyographic analyser (TeleMyo 16, Noraxon USA, Inc., Scottsdale, Arizona, USA) using Ag-AgCl electrodes (BLUE SENSOR model N-00-S, Medicotest, Ølstykke, Denmark). The signal collected at a 1000 Hz frequency from each channel was filtered with a 10-500 Hz passband filter and smoothed with a root mean square (RMS) algorithm with a 50 ms window.

For each recorded time interval, two variables were computed for each muscle: the area under the curve for the processed EMG signal and the mean amplitude. These two variables were normalized using the maximum voluntary contraction (MVC) as a reference for each muscle. The MVC of each muscle was recorded at each assessment

session in static standing, and was recorded bilaterally for each muscle for 10 sec. All participants started in static standing with unstable equilibrium created by varying their standing posture. Participants were asked to maintain the unstable position for at least 10 sec while the recording was taken. The only assistance permitted was light touch with a finger on the therapist. Unstable equilibrium for the MVC measurement of the tibialis anterior was created by standing on the heels with the toes extended. For the MVC of the soleus, the knees and hips were slightly bent while raising the heels slightly off the floor. For the MVC of the lateral and medial gastrocnemius, participants stood in a position of maximum plantar flexion, with the heels fully off the floor. The mean amplitude value of the recorded 10 sec of the processed EMG signal of each muscle was used as a MVC reference value for the normalization process.

During testing in static standing with opened eyes, participants kept their eyes fixed on a Y-shaped mark located in front of them at approximately eye-level. Their feet were placed in a comfortable position rather than a standardised position because of the variability in the morphology of the lower limb among individuals with DS [2] The tester requested static posture, waited 5 to 10 sec for the individual to become steady, and recorded data for 30 sec. At the second 15 of the recording, the tester gave a verbal indication of time, as well as when the recording was finished. After a 30-sec break, the same protocol was repeated with the closed eyes using a bandage.

For each 30-sec electromyographic recording (with open and closed eyes) the following variables were calculated as a percentage of the MVC: area under the curve and mean amplitude.

Dance programme

Participants in both groups followed an 18-week PA programme (two 90 min sessions per week) based on classical, modern, and creative dance. Volunteers in the CG performed these activities in a college course during the same timeframe that school

students with DS devoted to physical education and art. Sessions were led by two physiotherapists with special experience in dance and body expression and were conducted in classrooms especially designed for dance and PA. Both classrooms had the same materials: elastic bands, exercise balls, rings, mats, mirrors, and a ballet barre.

The same programme was performed by both groups. It consisted of warm-up activities (5-10 min), abdominal strengthening, lumbar and ballet barre exercises (15 min), proprioception and balance exercises with opened eyes and closed eyes (20 min), choreography (20 min), improvisation exercises and image recognition in a mirror (15 min), and relaxation (5-10 min). The DS group received greater explanation and demonstration of the exercises during the first two weeks to ensure understanding. Adherence to the programme by both groups was over 90%.

Statistical analysis

For the descriptive data, differences between groups were analysed by Mann-Whitney U test. Differences between the groups for variables in the time domain (area and mean amplitude) were also analysed by Mann-Whitney U test, and intra-group differences in pre- and post-training values were analysed by Wilcoxon test. An ANOVA was used to assess differences in pre- and post-exercise changes between groups. Analysis was performed with IBM-SPSS version 20 for Windows (IBM Corp., Armonk, NY, USA).

Results

Participants characteristics

Table 1 presents the characteristics of the participants. Eleven individuals in the DS group (4 men and 7 women) and in the CG (6 men and 5 women). According our assessment of the classification of the degree of disability in the DS group, one person has a low degree and ten people have a moderate degree.

The only significant differences were in the average values for height ($p < .01$) and BMI

(p = .02), due to the morphological differences associated with DS. Height values were higher in CG. BMI was higher in DS group.

Comparisons between the CG and DS group

Opened eyes condition in pre-training

Significant differences between the CG and DS group were observed in the tibialis anterior (area and mean amplitude p = .01) and soleus (area and mean amplitude p = .04) of the left leg, and the lateral gastrocnemius (area and mean amplitude p = .03) of the right leg. (Table 2)

Closed eyes condition in pre-training

Significant differences between the CG and DS group were observed in the tibialis anterior (area and mean amplitude p < .01) and soleus (area and mean amplitude p = .03) of the left leg, and the lateral gastrocnemius (area and a mean amplitude p = .03) of the right leg. (Table 2)

Opened eyes condition in post-training

Significant differences between the CG and DS group were observed in the lateral gastrocnemius (area and mean amplitude p = .02) and soleus (area and mean amplitude p < .01) of the left leg and the medial gastrocnemius (area p = .03) and lateral gastrocnemius (area and mean amplitude p < .01) of the right leg. (Table 3)

Closed eyes condition in post-training

Significant differences between the CG and DS group were observed in the soleus (area and mean amplitude p < .01) of the left leg and lateral gastrocnemius (area and mean amplitude p < .01) of the right leg. (Table 3)

Comparison between the opened eyes and closed eyes conditions.

Pre-training condition in the CG and DS group

In the CG, significant differences between the opened eyes and closed eyes conditions were observed in the soleus (area $p = .02$ and mean amplitude $p = .03$) of the right leg, with an increase in EMG activity in the closed eyes condition. (Table 4)

Post-training condition in the CG and DS group

In the CG, significant differences between the opened eyes and closed eyes conditions were observed in the soleus (mean amplitude $p = .04$) of the left leg and the medial gastrocnemius (area $p = .02$) of the right leg, with an increase in EMG activity in the closed eyes condition. In participants with DS, significant differences between the opened eyes and closed eyes conditions were observed in the tibialis anterior (area and average $p = .03$) of the left leg, with a decrease in EMG activity observed with the closed eyes. (Table 5)

Comparison between pre- and post-training situations.

Opened eyes condition in the CG and DS group

In the CG, significant differences between pre- and post-training situations were observed in the soleus (area and average $p < .01$) of the left leg, with a decrease in EMG activity post-training. In the DS group, no significant differences were observed pre- and post-training. (Table 6)

Closed eyes condition in the CG and DS group

In the CG, significant differences between pre- and post-training situations were observed in the tibialis anterior (area and mean amplitude $p = .02$) and soleus (area and mean amplitude $p = .03$) of the left leg with an increase in EMG activity in the tibialis anterior and a decrease in the soleus. In participants with DS, no significant differences between pre- and post-training situations were observed. (Table 6)

Discussion

Comparisons between the groups in pre-training

When comparing groups in the opened eyes condition, we noted that young people with DS exhibited more muscle activity, although the differences were significant only in the tibialis anterior, soleus and lateral gastrocnemius. In the closed eyes condition, these differences were also observed. In our previous studies, we observed a large displacement of the COP in the group with DS[41]which makes us think that although there is a muscle overexertion stabilisation effect, it is potentially ineffective at reducing COP displacement. Other authors have analysed muscle activity by EMG in people with DS, although many have studied the evolution of gait from childhood to adolescence or adulthood[16,21,42]. When analysing standing position, authors analysing have observed increased activation and co-activation of agonist-antagonist muscle groups in people with DS[4,19,42,43], which coincides with our results. Postural adjustments and pre-adjustments during the execution of exercises can be altered. In children (1-6 years), Shumway-Cook[18] observed latencies in muscle responses at the ankle during standing balance perturbations. Their results showed that muscle responses were delayed, with longer latencies than the CG. A distinct evolution in the organization of these muscle responses was also observed according to age group. More recently, changes in people with DS have been observed in the transition from adolescence to adulthood; adults tend to have longer latencies in muscle response but are better able to adjust and adapt to various situations[20]. With regard to participant age, that study group was comparable to ours. Differences in people with DS have also been observed in muscle activation and the stabilising role of the muscles[17]. We know that the role of the joint-stabilising muscles is important for the implementation of standing balance exercises[44]. The role of anticipatory postural adjustments in unstable conditions is extremely important, as they should enable a response to varying types of instability in order to provide improved stability and performance of tasks[45]. Probably,

the high degree of muscle activity observed in DS group is related to compensatory safety strategies.

Comparisons between groups in post-training situations

Differences between the groups, with the opened eyes, were smaller following training, and were observed in the plantar flexors (soleus and gastrocnemius) but not in the tibialis anterior. Essentially, the behaviour of the tibialis anterior became more similar between the two groups. The differences in activation of the tibialis anterior likely disappeared because of a decrease in muscle activity in the DS group following training, while the tibialis anterior remained more active in the CG. It would have been useful to assess COP position in relation to the changes in activation of the flexor and extensor muscles. This would have allowed us to analyse whether the change in the behaviour of the flexors and extensors in both groups was due to a change in the positioning of the COP after training. In the closed eyes condition, differences between groups also disappeared for the tibialis anterior following training because the CG displayed increased activity while activation in the DS group decreased. These changes may be due to repositioning of the COP after training, which entails changes in the stabilising activity of the flexor and extensor muscles. In our previous study, we observed that the DS group demonstrated improved stability of the COP with the opened eyes while the CG demonstrated improvements with the closed eyes[14]. It is possible that the DS group gained stability with the opened eyes by learning to better integrate visual signals, while the CG learned to gain stability in the more difficult condition for them, with the closed eyes, through the improved use of touch and proprioceptive information. Perhaps these improvements stabilise the COP as well as result in position change.

Intragroup comparisons between opened eyes and closed eyes conditions

When comparing each group according to visual condition before the programme implementation, the CG demonstrated increased activation of the soleus with the closed eyes. Activity in the extensors tended to decrease, but with no statistically significant differences. In contrast, the DS group showed no difference in muscle activation between the two visual conditions. We think that this difference in behaviour could be due to better sensory integration by the CG. A lack of integration of visual signals in the DS group may explain the absence of differences in terms of muscle response from one visual condition to another. Several theories explain the pathophysiologic cause of postural control deficits in people with DS, including deficits in proprioception, the somatosensory system[4], and cerebellum[18]. Our observations support a possible deficit in the use of sensory information, in this case, visual information. This would result in a lack of differences in muscle reaction based on visual information.

Following training, the CG maintained increases in soleus activation and displayed some increases in gastrocnemius activation as well. The DS group displayed a trend towards reduced activity in the tibialis anterior. These changes caught our attention. In the CG with the closed eyes, the muscles were more active, but only in the plantar flexors (soleus, gastrocnemius); although this is more evident post-training. However, in the DS group, differences were observed in the tibialis anterior, with lower activation with the closed eyes post-training, when no differences were observed before. Again, we can correlate this finding to our previous studies regarding the behaviour of COP. There, we could see that the CG demonstrated improved control of their COP with the closed eyes after training (just as the eyes were also closed when the differences in flexor activity increased). We also observed that people with DS demonstrated improved control of their COP with their opened eyes (just as we observed in this study with the action of the tibialis muscle, which was higher with the opened eyes). Therefore, we think that the CG

learned to control their COP in the closed eyes condition by using their muscles while the DS group did this with opened eyes.

Again, it would have been useful to assess the position of the COP in relation to the support base to see if predominant activation of the flexor or extensor muscles corresponds to different positions of the COP. Similarly, it might be useful to perform an assessment by muscle group instead of individual muscles in order to study muscle group activity via flexor or extensor moments.

Intragroup comparison between pre-training and post training situations

The CG exhibited greater pre- to post-training differences than the DS group. In the CG, less activation of the soleus was observed in the opened eyes condition after the implementation of the programme. However, this group displayed higher activation of the tibialis anterior with the closed eyes after training.

We must also mention the variability in the results of the subjects in the DS group, which is consistent with the findings of other authors[46]. This variability could explain the discordant fact that after training, minor differences between the DS group and CG were detected, while, in contrast, the intragroup pre- and post-training differences were not significant in the DS group.

Limitations and strengths

One limitation of the study was the sample size. The sample was intentional, as a compact group from a single special education school. It did not allow for a control group within the DS group. We were also not able to separate the groups by gender. We were also unable to perform long-term follow-up since most students in the study transitioned from the education centre to a workplace. On the other hand, it would have been interesting to be able to study both lower extremities and to compare the behaviour of their musculature.

On the strengths side, the sample was very well controlled and confined to the same level

of disability. Since the students were from a single centre, good dance programme monitoring was ensured. The consistency between the programmes applied to the DS group and CG was stringently maintained. Our study provides data for the evaluation of biomechanics and neurophysiology in DS subjects.

Conclusions

In static standing, differences in the behaviour of the stabilising ankle musculature have been observed in young adults with DS as compared to a control group. In general, the DS group displayed higher muscle activation levels. However, the number of muscles showing significant differences was reduced following the application of an 18-week PA programme based on dance.

The activity in the muscles of the CG differed depending on the presence or absence of visual information. Young people with DS showed no differences in muscle behaviour between opened eyes and closed eyes conditions before programme, although a difference in one muscle appeared after training.

When comparing the overall results before and after the implementation of the programme, the CG showed changes in their muscle behaviour. These differences were not significant in people with DS, who showed significant variability overall. Nevertheless, less differences were observed between both groups after training than before.

In the future we would like to expand our sample and carry out long-term follow-up. It would also be interesting to analyse the position of the COP along with the parameters already analysed in this study. Additionally, the analysis of the responses of each muscle should be extended to an analysis by muscle group for the ankle flexors and extensors. We also want to take into account the non-dominant limb and compare its muscular behaviour with that of the dominant limb.

Conflict of interest

There are no potential conflicts of interest that may affect the contents of this work.

Ethics Approval: IRB of Blanquerna Faculty of Psychology, Education and Sport Sciences, University Ramon Llull.

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Table 1 Descriptive characteristics of the sample

	CG (n=11)		DSG (n=11)		
Parameter	M	(SD)	M	(SD)	p
Age (years)	20.27	(2.05)	20.55	(1.37)	.44
Height (cm)	1.68	(0.11)	1.50	(0.11)	**<.01**
Weight (kg)	63.64	(10.56)	60.00	(10.04)	.56
BMI (kg/m²)	22.47	(3.20)	26.81	(4.46)	**.02**

Abbreviations: CG, control group; DSG, Down Syndrome group; M, mean; SD, standard deviation; BMI, body mass index.

p<.05 is considered significant (displayed in boldface).

Table 2 Comparison of EMG values between the CG and DS group on opened eyes and closed eyes conditions in pre-training

		OE					CE				
		CG		DS			CG		DS		
Parameter of EMG signal[a]		M	(SD)	M	(SD)	p[b]	M	(SD)	M	(SD)	p[b]
TA-L	A	52.16	(20.52)	114.25	(52.05)	**.01**	50.51	(20.01)	112.61	(52.64)	**<.01**
	MA	1.68	(.65)	3.70	(1.68)	**.01**	1.64	(.65)	3.65	(1.72)	**<.01**
GM-L	A	154.34	(113.90)	294.55	(208.35)	.08	170.50	(133.85)	278.31	(192.16)	.14
	MA	5.03	(3.74)	9.56	(6.84)	.09	5.55	(4.39)	9.04	(6.25)	.14
GL-L	A	132.39	(108.30)	185.57	(125.64)	.50	134.25	(108.68)	206.52	(151.42)	.35
	MA	4.30	(3.56)	6.01	(4.07)	.42	4.37	(3.55)	6.69	(4.90)	.31
So-L	A	184.43	(111.37)	310.50	(160.30)	**.04**	184.99	(124.51)	343.00	(191.51)	**.03**
	MA	5.97	(3.65)	9.99	(5.25)	**.04**	6.01	(4.07)	11.12	(6.19)	**.03**
TA-R	A	77.90	(70.38)	137.66	(104.56)	.16	58.28	(26.24)	119.98	(88.86)	.07
	MA	2.46	(2.03)	4.47	(3.41)	.18	1.89	(.83)	3.88	(2.88)	.07
GM-R	A	272.48	(216.30)	374.81	(212.88)	.18	321.38	(228.03)	390.06	(293.03)	.63
	MA	8.84	(7.08)	12.39	(7.26)	.14	10.43	(7.41)	12.64	(9.41)	.46
GL-R	A	125.89	(132.88)	243.81	(142.89)	**.03**	145.26	(176.21)	226.51	(108.85)	**.03**
	MA	4.10	(4.38)	7.86	(4.68)	**.03**	4.72	(5.76)	7.37	(3.58)	**.03**
So-R	A	216.98	(163.99)	283.91	(181.18)	.16	244.84	(185.54)	282.31	(184.22)	.54
	MA	7.06	(5.42)	9.18	(5.80)	.18	7.96	(6.08)	9.20	(6.04)	.58

Abbreviations: EMG, electromyography; OE, opened eyes; CE, closed eyes; CG, control group; DS, Down syndrome group; M, mean; SD, standard deviation; L, left leg; R, right leg; TA, tibialis anterior; GM, Gastrocnemius medialis; GL, Gastrocnemius lateralis; So, Soleus; A, area under the curve for the processed EMG signal; MA, mean amplitude of the processed EMG signal.

[a]EMG values are dimensionless because they are normalized.

[b]$p<.05$ is considered significant (displayed in boldface).

Table 3 Comparison of EMG values between the CG and DS group on opened eyes and closed eyes conditions in post-training

		OE					CE				
		CG		DS			CG		DS		
Parameter of EMG signal[a]		M	(SD)	M	(SD)	p[b]	M	(SD)	M	(SD)	p[b]
TA-L	A	61.82	(22.86)	87.79	(42.13)	.07	75.12	(41.09)	85.24	(42.65)	.43
	MA	2.02	(.74)	2.79	(1.38)	.11	2.45	(1.34)	2.75	(1.39)	.56
GM-L	A	130.18	(72.93)	172.77	(117.72)	.43	159.56	(105.98)	191.51	(179.62)	.76
	MA	4.29	(2.41)	5.47	(3.77)	.51	5.20	(3.44)	6.20	(5.88)	.76
GL-L	A	113.88	(83.05)	186.46	(86.71)	**.02**	116.47	(82.58)	165.38	(57.11)	.05
	MA	3.74	(2.72)	5.88	(2.57)	**.02**	3.79	(2.66)	5.40	(1.81)	.05
So-L	A	107.73	(42.97)	314.41	(202.51)	**<.01**	116.06	(43.44)	240.36	(133.76)	**<.01**
	MA	3.54	(1.41)	7.86	(4.56)	**<.01**	3.79	(1.41)	7.73	(4.28)	**<.01**
TA-R	A	65.13	(32.00)	98.16	(51.61)	.09	62.46	(34.38)	90.95	(49.44)	.11
	MA	2.13	(1.03)	3.13	(1.66)	.10	2.04	(1.11)	2.93	(1.60)	.11
GM-R	A	236.33	(184.49)	429.19	(296.37)	**.03**	300.55	(167.48)	399.53	(250.19)	.35
	MA	8.91	(5.66)	13.36	(8.43)	.09	9.78	(5.33)	12.90	(8.11)	.35
GL-R	A	82.29	(43.88)	240.40	(228.39)	**<.01**	83.72	(42.22)	217.41	(162.06)	**<.01**
	MA	2.70	(1.43)	7.41	(6.48)	**<.01**	2.73	(1.36)	7.02	(5.26)	**<.01**
So-R	A	134.84	(57.34)	286.52	(233.61)	.10	159.02	(82.55)	266.32	(194.91)	.25
	MA	4.41	(1.85)	8.96	(7.09)	.11	5.19	(2.68)	8.60	(6.33)	.25

Abbreviations: EMG, electromyography; OE, opened eyes; CE, closed eyes; CG, control group; DS, Down syndrome group; M, mean; SD, standard deviation; L, left leg; R, right leg; TA, tibialis anterior; GM, Gastrocnemius medialis; GL, Gastrocnemius lateralis; So, Soleus; A, area under the curve for the processed EMG signal; MA, mean amplitude of the processed EMG signal.

[a]EMG values are dimensionless because they are normalized.

[b]$p<.05$ is considered significant (displayed in boldface).

Table 4 Comparison of EMG values between different visual condition in pre-training

		CG					DS				
		OE		CE			OE		CE		
Parameter of EMG signal[a]		M	(SD)	M	(SD)	p[b]	M	(SD)	M	(SD)	p[b]
TA-L	A	52.16	(20.52)	50.51	(20.01)	.64	114.25	(52.05)	112.61	(52.64)	.39
	MA	1.68	(.65)	1.64	(.65)	.58	3.70	(1.68)	3.65	(1.72)	.58
GM-L	A	154.34	(113.90)	170.50	(133.85)	.14	294.55	(208.35)	278.31	(192.16)	.80
	MA	5.03	(3.74)	5.55	(4.39)	.10	9.56	(6.84)	9.04	(6.25)	.88
GL-L	A	132.39	(108.30)	134.25	(108.68)	.81	185.57	(125.64)	206.52	(151.42)	.45
	MA	4.30	(3.56)	4.37	(3.55)	.93	6.01	(4.07)	6.69	(4.90)	.39
So-L	A	184.43	(111.37)	184.99	(124.51)	.81	310.50	(160.30)	343.00	(191.51)	.88
	MA	5.97	(3.65)	6.01	(4.07)	.59	9.99	(5.25)	11.12	(6.19)	.88
TA-R	A	77.90	(70.38)	58.28	(26.24)	.24	137.66	(104.56)	119.98	(88.86)	.05
	MA	2.46	(2.03)	1.89	(.83)	.33	4.47	(3.41)	3.88	(2.88)	.16
GM-R	A	272.48	(216.30)	321.38	(228.03)	.10	374.81	(212.88)	390.06	(293.03)	.96
	MA	8.84	(7.08)	10.43	(7.41)	.10	12.39	(7.26)	12.64	(9.41)	.72
GL-R	A	125.89	(132.88)	145.26	(176.21)	.10	243.81	(142.89)	226.51	(108.85)	.96
	MA	4.10	(4.38)	4.72	(5.76)	.10	7.86	(4.68)	7.37	(3.58)	.72
So-R	A	216.98	(163.99)	244.84	(185.54)	**.02**	283.91	(181.18)	282.31	(184.22)	.96
	MA	7.06	(5.42)	7.96	(6.08)	**.03**	9.18	(5.80)	9.20	(6.04)	.52

Abbreviations: EMG, electromyography; OE, opened eyes; CE, closed eyes; CG, control group; DS, Down syndrome group; M, mean; SD, standard deviation; L, left leg; R, right leg; TA, tibialis anterior; GM, Gastrocnemius medialis; GL, Gastrocnemius lateralis; So, Soleus; A, area under the curve for the processed EMG signal; MA, mean amplitude of the processed EMG signal.

[a]EMG values are dimensionless because they are normalized.

[b]$p<.05$ is considered significant (displayed in boldface).

Table 5 Comparison of EMG values between different visual condition in post-training

Parameter of EMG signal[a]		CG					DS				
		OE		CE			OE		CE		
		M	(SD)	M	(SD)	p[b]	M	(SD)	M	(SD)	p[b]
TA-L	A	61.82	(22.86)	75.12	(41.09)	1.00	87.79	(42.13)	85.24	(42.65)	**.03**
	MA	2.02	(.74)	2.45	(1.34)	.87	2.79	(1.38)	2.75	(1.39)	**.03**
GM-L	A	130.18	(72.93)	159.56	(105.98)	.11	172.77	(117.72)	191.51	(179.62)	.96
	MA	4.29	(2.41)	5.20	(3.44)	.13	5.47	(3.77)	6.20	(5.88)	.65
GL-L	A	113.88	(83.05)	116.47	(82.58)	.33	186.46	(86.71)	165.38	(57.11)	.45
	MA	3.74	(2.72)	3.79	(2.66)	.29	5.88	(2.57)	5.40	(1.81)	.72
So-L	A	107.73	(42.97)	116.06	(43.44)	.08	314.41	(202.51)	240.36	(133.76)	.33
	MA	3.54	(1.41)	3.79	(1.41)	**.04**	7.86	(4.56)	7.73	(4.28)	.51
TA-R	A	65.13	(32.00)	62.46	(34.38)	.86	98.16	(51.61)	90.95	(49.44)	.45
	MA	2.13	(1.03)	2.04	(1.11)	.88	3.13	(1.66)	2.93	(1.60)	.80
GM-R	A	236.33	(184.49)	300.55	(167.48)	**.02**	429.19	(296.37)	399.53	(250.19)	.29
	MA	8.91	(5.66)	9.78	(5.33)	.06	13.36	(8.43)	12.90	(8.11)	.39
GL-R	A	82.29	(43.88)	83.72	(42.22)	.16	240.40	(228.39)	217.41	(162.06)	.39
	MA	2.70	(1.43)	2.73	(1.36)	.16	7.41	(6.48)	7.02	(5.26)	.24
So-R	A	134.84	(57.34)	159.02	(82.55)	.09	286.52	(233.61)	266.32	(194.91)	.65
	MA	4.41	(1.85)	5.19	(2.68)	.06	8.96	(7.09)	8.60	(6.33)	.95

Abbreviations: EMG, electromyography; OE, opened eyes; CE, closed eyes; CG, control group; DS, Down syndrome group; M, mean; SD, standard deviation; L, left leg; R, right leg; TA, tibialis anterior; GM, Gastrocnemius medialis; GL, Gastrocnemius lateralis; So, Soleus; A, area under the curve for the processed EMG signal; MA, mean amplitude of the processed EMG signal.

[a]EMG values are dimensionless because they are normalized.

[b]$p<.05$ is considered significant (displayed in boldface).

Table 6 Comparison of EMG values between pre and post training situations on opened eyes and closed eyes condition

		OE									CE								
		CG					DS				CG					DS			
		Pre-training		Post-training			Pre-training		Post-training		Pre-training		Post-training			Pre-training		Post-training	
Parameter of EMG signal[a]		M	(SD)	M	(SD)	p[b]	M	(SD)	M	(SD)	p[b]	M	(SD)	M	(SD)	p[b]	M	(SD)	M	(SD)	p[b]
TA-L	A	52.16	(20.52)	61.82	(22.86)	.33	114.25	(52.05)	87.79	(42.13)	.44	50.51	(20.01)	75.12	(41.09)	**.02**	112.61	(52.64)	85.24	(42.65)	.37
	MA	1.68	(.65)	2.02	(.74)	.25	3.70	(1.68)	2.79	(1.38)	.37	1.64	(.65)	2.45	(1.34)	**.02**	3.65	(1.72)	2.75	(1.39)	.37
GM-L	A	154.34	(113.90)	130.18	(72.93)	.66	294.55	(208.35)	172.77	(117.72)	.11	170.50	(133.85)	159.56	(105.98)	.79	278.31	(192.16)	191.51	(179.62)	.37
	MA	5.03	(3.74)	4.29	(2.41)	.66	9.56	(6.84)	5.47	(3.77)	.09	5.55	(4.39)	5.20	(3.44)	.79	9.04	(6.25)	6.20	(5.88)	.37
GL-L	A	132.39	(108.30)	113.88	(83.05)	.93	185.57	(125.64)	186.46	(86.71)	.95	134.25	(108.68)	116.47	(82.58)	.59	206.52	(151.42)	165.38	(57.11)	.86
	MA	4.30	(3.56)	3.74	(2.72)	.93	6.01	(4.07)	5.88	(2.57)	.95	4.37	(3.55)	3.79	(2.66)	.59	6.69	(4.90)	5.40	(1.81)	.86
So-L	A	184.43	(111.37)	107.73	(42.97)	**<.01**	310.50	(160.30)	314.41	(202.51)	.95	184.99	(124.51)	116.06	(43.44)	**.03**	343.00	(191.51)	240.36	(133.76)	.21
	MA	5.97	(3.65)	3.54	(1.41)	**<.01**	9.99	(5.25)	7.86	(4.56)	.21	6.01	(4.07)	3.79	(1.41)	**.03**	11.12	(6.19)	7.73	(4.28)	.21
TA-R	A	77.90	(70.38)	65.13	(32.00)	.53	137.66	(104.56)	98.16	(51.61)	.31	58.28	(26.24)	62.46	(34.38)	.53	119.98	(88.86)	90.95	(49.44)	.17
	MA	2.46	(2.03)	2.13	(1.03)	.53	4.47	(3.41)	3.13	(1.66)	.26	1.89	(.83)	2.04	(1.11)	.48	3.88	(2.88)	2.93	(1.60)	.17
GM-R	A	272.48	(216.30)	236.33	(184.49)	**.72**	374.81	(212.88)	429.19	(296.37)	.68	321.38	(228.03)	300.55	(167.48)	1.00	390.06	(293.03)	399.53	(250.19)	.77
	MA	8.84	(7.08)	8.91	(5.66)	.79	12.39	(7.26)	13.36	(8.43)	.77	10.43	(7.41)	9.78	(5.33)	1.00	12.64	(9.41)	12.90	(8.11)	.77
GL-R	A	125.89	(132.88)	82.29	(43.88)	.33	243.81	(142.89)	240.40	(228.39)	.59	145.26	(176.21)	83.72	(42.22)	.18	226.51	(108.85)	217.41	(162.06)	.59
	MA	4.10	(4.38)	2.70	(1.43)	.33	7.86	(4.68)	7.41	(6.48)	.59	4.72	(5.76)	2.73	(1.36)	.18	7.37	(3.58)	7.02	(5.26)	.59
So-R	A	216.98	(163.99)	134.84	(57.34)	.08	283.91	(181.18)	286.52	(233.61)	.68	244.84	(185.54)	159.02	(82.55)	.16	282.31	(184.22)	266.32	(194.91)	.68
	MA	7.06	(5.42)	4.41	(1.85)	.09	9.18	(5.80)	8.96	(7.09)	.68	7.96	(6.08)	5.19	(2.68)	.16	9.20	(6.04)	8.60	(6.33)	.68

Abbreviations: EMG, electromyography; OE, opened eyes; CE, closed eyes; CG, control group; DS, Down syndrome group; M, mean; SD, standard deviation; L, left leg; R, right leg; TA, tibialis anterior; GM, Gastrocnemius medialis; GL, Gastrocnemius lateralis; So, Soleus; A, area under the curve for the processed EMG signal; MA, mean amplitude of the processed EMG signal.

[a]EMG values are dimensionless because they are normalized.

[b]$p<.05$ is considered significant (displayed in boldface).