

Feasibility of the assessment of the H-reflex in adult dancers and non-dancers with and without Down syndrome: A pilot study.

Núria Massó-Ortigosa¹; Ferran Rey-Abella¹; Myriam Guerra-Balic²; Raimon Milà-Villaruel¹; Guillermo R. Oviedo^{1,2}

¹Blanquerna School of Health Science. University Ramon Llull. 326-332 Padilla Street, 08025, Barcelona, Spain.

²Blanquerna Faculty of Psychology, Education and Sports Sciences. University Ramon Llull. 34 Císter Street, 08022, Barcelona. Spain.

Corresponding author: Guillermo R. Oviedo: guillermorubeno@blanquerna.url.edu; Tel.: +34-932-533-000

Acknowledgements: The authors would like to thank the participants for their willingness to be part in this study. Also, we would like to thank Danza Down Compañía Elías Lafuente and the Institut del Teatre de Barcelona for their assistance and invaluable help in data collection.

Funding: This study was partially supported by the University Ramon Llull and Obra Social La Caixa (references: 2016-URL-Trac-016 and 2018-URL-Proj-069); by the FPCEE-Blanquerna (reference: APR-FPCEE1819/01) and, by the Spanish Ministry of Economy, Industry, and Competitiveness (I+D+i Ref: DEP2017-86862-C2-1-R).

Abstract: The analysis of monosynaptic Hoffman's reflex (H-reflex) involves recording the response to electrical stimulation of Ia-afferent fibers from the muscle spindle. The H-reflex can be used as a probe to study spinal neuronal pathways and mechanisms at rest and during movement in humans. The purpose of this study was to analyze the feasibility of the assessment of the H-reflex in people with Down syndrome (DS), and to compare it between adult dancers and non-dancers with and without DS. Twenty-five participants were included and divided into four groups (6 non-dancers and 6 dancers with DS and, 7 non-dancers and 6 dancers without DS). The H-reflex was recorded at the level of the soleus muscle in its central area. We analyzed the H response in three different conditions: decubitus prone, static standing position with open eyes and closed eyes. Non-dancers with DS showed a faster H-reflex latency than both groups without DS (all $p < .005$). In the present study, we provide evidence of the feasibility of eliciting the H-reflex in adults with DS. Interestingly, the H-reflex was present in decubitus position but not in standing position in most non-dancers with DS and dancers without DS. The data from this study can help to perform future research in adults with DS and the development of full-scale studies to analyze this variable in adults with intellectual disability with and without DS.

Key words: H-reflex, Down syndrome, adult, dance, posture.

Running title: H-reflex in adults with and without Down syndrome

Introduction

The monosynaptic Hoffman's reflex (H-reflex) depends on the state of the afferent or sensory pathways, the spinal segment, and the efferent or motor pathways, providing useful data for neurological studies (Burke 2016; Gutierrez Rivas et al. 2000; Knikou 2008). It involves recording the response generated by the electrical stimulation of type Ia-afferent fibers from the muscle spindle. Continuing to increase the intensity of the electrical stimulus beyond that required for an H-reflex results in direct stimulation of the voluntary alpha-motoneuron which axons travel directly from the site of stimulation to the neuromuscular junction to produce a motor response or M-wave (Burke 2016; Marchand-Pauvert and Nielsen 2002; Pierrot-Deseilligny and Mazevet 2000).

The H-reflex is used when there is suspicion of involvement of spinal nerve roots at the cervical and lumbosacral levels and in polyneuropathies of various etiologies, and also in the study of hyperreflexia (Burke 2016), to analyze the excitability of motor neurons and the motor control (Pierrot-Deseilligny and Mazevet 2000). Apart from its role as an aid for clinical diagnosis, the H-reflex has been related to static postural control, and can be modulated through mechanisms of presynaptic inhibition (Chen et al. 2010).

As a peripheral reflex, it is subject to the influence of cortical structures. In the standing position, it is related to changes in the oscillation of the center of gravity and postural control (Chen and Zhou 2011). In circumstances where a motor variability must be prevented or controlled, these cortical structures appear to play a dominant role. Also, the level of attention causes changes in the amplitude of the H-reflex (König et al. 2017).

Alsubiheen et al. (2017) observed increases in the amplitude of the H-reflex in diabetic adults after an 8-week training based on tai-chi and mental imagery. Training based on the passive stretching of the plantar flexor muscles modifies the tendon reflex and the H-

reflex (Guissard and Duchateau 2004). Changes are also observed when performing standing and balance training with a reduced base of support (Trimble and Koceja 2001).

Regarding the type of exercise training, changes have been observed in the amplitude after endurance training (Vila-Chã et al. 2011) but no changes or adaptations were seen after four weeks of low intensity resistance training (Colomer-Poveda et al. 2017). It was also observed that the type of training and the composition of the muscle fiber determines differences in the responses of the H-reflex (Kumar et al. 2012). Other studies found that aerobic training increases its amplitude (Casabona et al. 1990; Maulen Arroyo et al. 2000). In contrast, professional dancers show smaller H-reflex responses (Nielsen et al. 1993; Ryder et al. 2010), or a decrease in osteotendinous reflexes (Goode and Van Hoven 1982; Koceja et al. 1991).

König et al. (2017) have used force platforms and the H-reflex to assess simultaneously the stability of the center of pressure (COP) and some neurophysiological mechanisms that take part in different circumstances. These authors observed that the lack of visual information when maintaining balance with the eyes closed is associated with an increased reliance on Ia fibers, although their role is limited when difficulties are added (König et al. 2017). Balance training causes changes in stability and neurological mechanisms, however, it seems that age may hinder these neurological adaptations (Gruber et al. 2007).

In persons with Down syndrome (DS), improvements have been observed in the control of COP, assessed using a force platform, after training with a Wobble Board (Park 2014) or on a vibratory platform (Villarroya et al. 2013), however, neither the H-reflex nor the M-wave were assessed.

People with intellectual disability (ID) due to DS or other ID etiology usually have poor postural control, which could be due to a lack of integration and dysfunction of the

higher centers (Rigoldi et al. 2016). However, the role played by peripheral pathways in a multifactorial system such as balance is not clear. The study of the H-reflex represents a good approach for assessing the degree of activity of the peripheral nervous system related to the stretch reflex, and can provide data for a better understanding of pathophysiological mechanisms. The assessment of the H-reflex is a non-invasive study, but it requires a certain degree of tolerance to the electrical stimulus. Also, the person being assessed should understand the test and should be able to maintain the requested positions during the test.

Comparing the H response in adults with DS vs non-DS is interesting because it depends on peripheral circuits that are part of the postural control. Furthermore, it will be helpful to know how dancing can influence the peripheral factor in adults with and without DS, in order to help the design of strategies for improving balance. To the best of our knowledge, there is a lack of studies which aim to determine the feasibility of performing the H-reflex and M-wave assessments in adults with DS. Also, there are no studies comparing these responses in adult dancers and non-dancers with or without DS.

The aim of this study, therefore, was (1) to determine the feasibility of performing the H-reflex and M-wave assessments in adult dancers and non-dancers with DS; and (2) to evaluate and compare the H-reflex and M-wave responses in adult dancers and non-dancers with and without DS in three different conditions (i. prone decubitus; ii. static standing position with open eyes; iii. static standing position with closed eyes).

Methods

Study design and participants

This cross-sectional study included 12 participants with DS and 13 participants without DS. The sample was divided into four subgroups: group A (n = 6), non-dancer persons with DS; group B (n = 6), persons with DS who practiced dance more than three hours a week and for at least three years; group C (n = 7), people without ID who did not

engage in dancing or similar activities such as rhythmic gymnastics or others; and group D (n = 6), students in the final year of the advanced degree in classical and contemporary dance.

Non-dancers with DS were recruited from special education schools, associations and foundations for people with intellectual disabilities from the region of Barcelona. The dancers with DS were recruited from a special contemporary ballet school for people with intellectual disabilities from the region of Madrid. Adults non-dancers without DS were recruited from different universities in Barcelona and, the dancers without DS were recruited from the Higher Dance Academy in Barcelona.

To be included in this study, all participants should be aged from 16 to 30 years. Dancers with and without DS should be training ≥ 3 times a week at least 1 hour, during at least 3 years. Participants with moderate, severe or profound ID, people with neuromuscular diseases, severe vestibular and/or vision impairment, people treated with drugs that might affect balance or those who could not tolerate the study and/or follow instructions were not included in the study.

Procedures

Before beginning the study, two meetings were held with the participants and their parents/legal tutors. During the first meeting, testing procedures, the potential benefits, associated risks and the period of time required for the study were explained to the participants and their parents/legal tutors. During the second meeting, the various assessments were carried out. A rigorous procedure for obtaining consent for the study was set out to ensure that participants were fully informed, autonomous, and empowered with regard to their participation. All participants and parents and/or legal guardians provided signed informed consent. Subsequently, demographic, background and physical examination were collected from each participant. A health screening questionnaire was completed by each participant's parent(s) and/or guardian. The ID classification was obtained from the

patients' medical records; all the participants with DS were diagnosed with mild ID according to the Spanish National Government classification (Spain 2016). All participants were able to walk unaided and did not present motor impairments.

The study was approved by the Institutional Research Ethics Committee and follows the Helsinki guidelines for ethical behavior (Ethical code: URL 2014_2015_010)

Anthropometric measurements

Height was measured to the nearest 0.1 cm using a stadiometer (Seca 225, Seca, Hamburg, Germany). Weight was measured to the nearest 0.1 kg on a digital scale (Seca 861, Hamburg, Germany) with the subject wearing lightweight clothing and no shoes. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Electrical stimulation

The dominant limb of each participant was determined by asking them to kick a ball at a target placed two meters away. On the dominant limb, and after cleaning the skin, the H-reflex and M-wave were recorded in three different conditions: in prone position with the foot relaxed and off the stretcher; in static standing position with open eyes (OE) looking at a fixed point, and in static standing position with closed eyes (CE). The trials were performed with 10 min rest between them.

The protocol established by De Lisa & Brozovich (1983) was applied by stimulating the tibial nerve in the popliteal fossa. The H-reflex and M-wave were recorded at the level of the soleus muscle in its central area and a reference electrode was placed in the tibial malleolus of the same limb (Botter and Vieira 2017; De Lisa and Brozovich 1983; Gutierrez Rivas et al. 2000). Bipolar electrodes were used to electrically stimulate the tibial nerve and to record the response. Rectangular stimuli of 0.5 ms duration and a frequency of 5 Hz were applied (Medtronic Keypoint system, Medtronic, Minneapolis, Minnesota, USA), increasing

the intensity of the stimulus progressively until maximum responses were obtained.

Latencies and amplitudes of the H and M responses were recorded in each case, and the ratio of the peak-to-peak maximal H-reflex amplitude to maximal M-wave amplitude (H/M) was recorded in terms of amplitude.

Statistical analysis

Descriptive statistics were obtained for all variables. The latency and amplitude of the H-reflex; M-wave; H-M latency and the H/M amplitude ratio were analyzed and compared between the four study groups. The possible changes in relation to the different recording conditions (prone position, standing with OE and standing with CE) were also observed in each of the groups.

To check the normality of the data, the Kolmogorov-Smirnov and Shapiro Wilk normality tests were used. Even though the data were normally distributed and given the small size of each group, we based our analysis on non-parametric tests. For the between-groups comparison, Kruskal-Wallis tests were performed and the difference between means was tested with Mann-Whitney U-tests. Finally, Wilcoxon matched-pairs signed-ranks test was used to analyze within-groups differences at different conditions. Correlation coefficient r was used to determine the effect sizes (Tomczak and Tomczak 2014).

To assess feasibility of the H-reflex and M-wave assessment, we compared the number of unsuccessful measurements with the total number of measurements to derive the percentage of all successful measurements. Based on previous literature, the feasibility was considered to be sufficient when the percentage of successful assessments exceeded 85% (Dijkhuizen et al. 2018; Waning et al. 2011).

The critical values for statistical significance were assumed at an alpha level $< .05$. Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) v22.0 (IBM SPSS Statistics, Chicago, IL, USA).

Results

The general characteristics of the participants are presented in Table 1. The participants from group C were taller than participants from group B ($p = .045$, $r = .55$).

All participants with DS (100%) tolerated the evocation of the H-reflex and M-wave in the prone decubitus position. When standing up, 91.67% (11 out of 12) of the DS participants tolerated the evocation of the H and M responses as only 1 participant from the group A did not tolerate the electric evocation of the H and M responses.

Within-group comparisons

In group A, except for one participant in the static standing position with OE, there were no H-reflex during the static standing position with OE. Also, there were no H-reflex during the static standing position with CE in participants from group A (table 2). In group D, the H-reflex was detected in only one participant during the static standing position with OE or CE (table 2).

The M-wave latency in group C was significantly faster during the static standing position with CE than in prone decubitus position ($p = .042$, $r = .77$).

In group D, the M-wave latency was faster during the static standing position with CE than in the same position with OE ($p = .027$, $r = .90$). Also, the M-wave amplitude was significantly higher in the prone position than the static standing position with CE ($p = .043$, $r = .82$)

Between-group comparisons

Between-group comparisons are showed in Table 3. In the prone decubitus position, the latency of the H-reflex in group A was slower than in groups C and D ($p = .034$, $r = .80$ and $p = .010$, $r = .77$, respectively). Regarding M-wave amplitude, it was lower in group A than in the rest of groups (A vs B: $p = .028$, $r = .64$; A vs C: $p = .008$, $r = .73$; A vs D: $p = .029$, $r = .63$). The H-M latency in group A was slower than in both groups without DS (A vs

C: $p = .015$, $r = .70$; A vs D: $p = .011$, $r = .77$). Finally, significant differences in the H/M amplitude ratio were found between groups A vs B ($p = .006$, $r = .83$); A vs D ($p = .028$; $r = .66$) and B vs C ($p = .032$, $r = .59$).

In the static standing position with OE, the M-wave latency was slower in group B than group C ($p = .046$, $r = .55$). Also, the H/M amplitude ratio was lower in group B than group C ($p = .027$, $r = .61$).

In the static standing position with CE, the M-wave latency was faster in group D than in DS groups (D vs A: $p = .035$, $r = .70$; D vs B: $p = .022$, $r = .66$).

When comparing the difference of the values of each variable at different position (i.e. prone decubitus position – static standing position with OE; prone decubitus position – static standing position with CE; static standing position with OE – static standing position with CE) we found significant differences in the M-wave amplitude (prone decubitus position vs static standing position with CE) between groups A vs D ($p = .028$, $r = .73$) (Figure 1) and, M-wave latency (static standing position with OE vs static standing position with CE) between group D vs B ($p = .033$, $r = .62$) and D vs C ($p = .016$, $r = .66$) (Figure 2).

Discussion

The present study shows that the measurement of the H-reflex and M-wave is feasible in adults with DS. A significant fact was the disappearance of the H-reflex in most of the non-DS adult dancers when they were in static standing position. Interestingly, the phenomenon was similar in most of adult non-dancers with DS.

It is known that physical activity influences the response of the H-reflex (Mynark & Koceja, 1997). This influence has not been studied in adults with ID. A recent study found that resistance training with instability improves the response of the H-reflex at rest in adults with Parkinson's disease, achieving similar values than healthy adults (Silva-Batista et al. 2019). However, up to the present no study have analyzed this reflex in persons with DS nor

its changes due to exercise training or physical activity. Therefore, the true extent of this phenomenon is unknown and analyzing the different parameters of this reflex in this specific population, dancers or not, is of great importance since this information will provide data and greater knowledge about the connection of the motor and sensory systems in the spinal cord in persons with DS. At the moment, and due to the lack of studies on the H-reflex in adults with DS, it is difficult to interpret these preliminary data.

Within-group comparisons

It should be pointed out that the H response of the participants from group A disappeared when they were in static standing position with CE and only one participant showed H response in static standing position with OE. In group D, except in one case, the H-reflex disappeared when the participants were in static standing conditions (table 2).

Different studies showed that the amplitude of the H-reflex in healthy people is higher in the prone decubitus position than when standing and have highlighted the different roles played by factors such as presynaptic inhibition, the vestibular apparatus or proprioceptors according to posture (Cecen et al. 2018; Knikou 2008). In our case, this finding was recorded only in the group of dancers and the group of non-dancers with DS, perhaps due to the small sample size. It is concordant with previous studies where most important changes were observed in dancers. In these previous studies different degrees of gain of the H-reflex were observed in different conditions of basic muscle contraction in both dancers and controls, although the similarity between the two groups were found only in the prone decubitus position. In the standing position, the gain was lower in dancers, and may be due to a greater role of supramedullary control and inhibitory mechanisms in this group in this position (Mynark and Kocejka 1997).

In the participants with DS, perhaps the phenomenon could be due to a security strategy, in which they use greater supraspinal mechanisms of motor control to face balance

challenges and a lower reliance on the lower spinal mechanisms. We also postulate that morphological anomalies, which are common in adults with DS (e.g., flat fee, knee valgus, hammer toe deformities), may influence the H response. A recent study found that flat feet have a lower H response of the abductor hallucis muscle (Huang et al. 2019).

We should also consider that different articular or cutaneous inputs may influence the H-reflex. In relation to these variations on the H-reflex, it was observed that different cutaneous or tactile inputs may promote changes in the H response (Espeit et al. 2017). Also, security strategies to face balance challenges may lead to co-contraction mechanisms between agonist and antagonist muscles, which may be related to smaller amplitude of the H response (Perez et al. 2007).

When analyzing the displacement of the COP in static standing position on a force platform, dancers without ID showed better control than practitioners without ID of other physical activities (Gerbino et al. 2007). In our study we analyzed different degrees of difficulty in standing with eyes either open or closed. A point that should be take into account in future studies is the influence of difficulties according to the type of surface and its stability, which would engage proprioception to a greater degree. Tokuno et al. (2009) observed that the amplitude of the H-reflex was lower in normal standing than in supported standing or sitting, and also observed differences when using an unstable surface. Bieć et al. (2014) observed that people with DS have a greater mid-lateral displacement of the COP when studying the static standing position on foam surface with eyes open or closed. Compared with adults without DS, these alterations could be due to the lack of proper integration of the visual information (Gutiérrez-Vilahú et al. 2016; Massó-Ortigosa et al. 2013).

As for the M-wave, in group C, its latency was faster when standing with CE than in decubitus (table 2). In group D, its latency was faster in standing with CE than with OE, and

the amplitude was lower in standing with CE than in decubitus (table 2). Poh et al. (2013) found changes in the amplitude of the motor evoked potential using transcranial stimulation, thus reflecting the function of the corticospinal tract. These authors observed that the amplitude increased when standing normally than in supported standing or sitting. In our study, since we obtained the M-wave through electrical stimulation of the tibial nerve, the corticospinal tract was not included.

Between-groups comparison

In prone decubitus position, group A showed the lowest amplitude of the M-wave, and as a result of that, a higher H/M amplitude ratio (table 3). However, no underlying differences were found in the amplitude of the H-reflex in this position in dancers with respect to non-dancers. Some studies report smaller amplitudes in professional dancers, in relation perhaps to Goode's observations about the lack of osteotendinous reflexes often seen in this population (Goode and Van Hoven 1982). A lower amplitude of the M-wave in group A may be due to a lower degree of activation of the alpha-motoneuron. In addition, we found differences in the latency of the H-reflex, which is shorter in group A than in groups C and D, but not when compared with dancers with DS (group B). It should be noted that the latency of the H-reflex can be influenced by height and length of lower limbs. Nevertheless, the H-M difference, which is not affected by the length of the lower limbs, was also lower in group A.

In static standing position with OE, the latency of the M-wave was longer in group B compared to C. When measuring these parameters with CE, the latency of the M-wave was longer in groups A and B with respect to group D. These findings seem to indicate that adults with DS present late and lower motor responses dependent on the alpha-motoneuron.

When changing from static standing position with OE to CE the M-wave latency varied from group to group, and was shortest in group D respect groups B and C. The amplitude of the M-wave in group D was greater in prone position than in standing position

with CE (table 3)

As far as we know, no studies have analyzed and compare these variables in adults with and without DS. As these reflexes participate in postural control and interact with upper neural pathways, we think it is important to analyze their behavior. The possible role of sight and proprioception is also interesting; in general, a greater understanding of these aspects may improve our ability to manage postural control problems in people with intellectual disabilities. Different studies observed improvements in the postural reflex of children with DS after applying neuro-sensory motor reflex integration therapies, and suggest that further research should be done to analyze the neurophysiological mechanism and biomechanical aspects affecting the reflex circuits parameters in children with DS (Masgutova et al. 2015, 2016).

What is more, changes are often observed in relation to age. Recently, it was observed that the H response is lower when anticipatory postural adjustments are required. Nevertheless, in older adults, this reduction in the H-reflex is lower and the response may even increase (Hortobágyi et al. 2018). People with DS show a worsening of their postural control with age (Rigoldi et al. 2011) which in turn affects the type and degree of plantar contact (Galli et al. 2016). We do not know what associations may exist between the worsening observed in the balance in people without ID (and above all in those with ID) and the changes that occur with age at the level of the peripheral fibers. For example, the Ia-afferent fibers, involved in the generation of the reflex analyzed here, lose effectiveness with age, accompanied by a greater degree of corticospinal excitability (S. Baudry et al. 2014; Stéphane Baudry and Duchateau 2012; Benjuya et al. 2004; Earles et al. 2000; Hortobágyi et al. 2018).

Limitations

There are some limitations that should be highlighted in the present study. First, it would have been preferable to perform the assessments of each position on three separate days, but this proved impossible for logistical reasons. The study of the H-reflex is considered valid and reliable (Hopkins et al. 2000) although some authors mention the lack of repeatability and the need to normalize the response not only based on the amplitude of the M-wave, but also on the intensity of the stimulus (Brinkworth et al. 2007). Second, the small sample size may have reduced the study's statistical power. Finally, it would be useful to compare the data obtained not only according to the presence/absence of sight, but also according to factors related to proprioception or touch (i.e., different types of contact surface).

Conclusion

The study of the H-reflex has been shown to be feasible in a group of people with DS. Also, this study proved to be useful for detecting different responses of the H-reflex and M-wave in dancers with and without DS. The results may be relevant to the study of neurophysiological adaptations to dance, and also will help further understanding of the neurophysiological mechanisms which cause the lack of postural control in people with ID.

Future research

Future research should analyze these variables with a larger sample size and analyze differences by age, sex and ID level. In addition, investigating the reflex contributions in varying postural conditions (e.g., lying down, sitting, standing, walking), COP, muscles contractions and tasks, flat fee, knee valgus, will help to better understand the mechanisms and function of the H-reflex modulation in the lower limb in persons with DS.

Compliance with Ethical Standards

Ethical Approval: all procedures performed in this study were in accordance with ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: the study was approved by the Institutional Review Board. All participants and parents/legal guardians signed an informed consent form.

Conflicts of Interest: the authors declare no conflict of interest.

References

- Alsubiheen, A., Petrofsky, J., Daher, N., Lohman, E., Balbas, E., & Lee, H. (2017). Tai Chi with mental imagery theory improves soleus H-reflex and nerve conduction velocity in patients with type 2 diabetes. *Complementary Therapies in Medicine, 31*, 59–64. doi:10.1016/j.ctim.2017.01.005
- Baudry, S., Penzer, F., & Duchateau, J. (2014). Input-output characteristics of soleus homonymous Ia afferents and corticospinal pathways during upright standing differ between young and elderly adults. *Acta Physiologica, 210*(3), 667–677. doi:10.1111/apha.12233
- Baudry, Stéphane, & Duchateau, J. (2012). Age-related influence of vision and proprioception on Ia presynaptic inhibition in soleus muscle during upright stance. *Journal of Physiology, 590*(21), 5541–5554. doi:10.1113/jphysiol.2012.228932
- Benjuya, N., Melzer, I., & Kaplanski, J. (2004). Aging-induced shifts from a reliance on sensory input to muscle cocontraction during balanced standing. *The journals of gerontology. Series A, Biological sciences and medical sciences, 59*(2), 166–171.
- Bieć, E., Zima, J., Wójtowicz, D., Wojciechowska-Maszkowska, B., Kręcisz, K., & Kuczyński, M. (2014). Postural stability in young adults with down syndrome in challenging conditions. *PLoS ONE, 9*(4), e94247. doi:10.1371/journal.pone.0094247

- Botter, A., & Vieira, T. M. (2017). Optimization of surface electrodes location for H-reflex recordings in soleus muscle. *Journal of Electromyography and Kinesiology*, *34*, 14–23. doi:10.1016/j.jelekin.2017.03.003
- Brinkworth, R. S. A., Tuncer, M., Tucker, K. J., Jaberzadeh, S., & Türker, K. S. (2007). Standardization of H-reflex analyses. *Journal of Neuroscience Methods*, *162*(2007), 1–7. doi:10.1016/j.jneumeth.2006.11.020
- Burke, D. (2016). Clinical uses of H reflexes of upper and lower limb muscles. *Clinical Neurophysiology Practice*, *1*, 9–17. doi:10.1016/j.cnp.2016.02.003
- Casabona, A., Polizzi, M. C., & Perciavalle, V. (1990). Differences in H-reflex between athletes trained for explosive contractions and non-trained subjects. *European Journal of Applied Physiology and Occupational Physiology*, *61*(1–2), 26–32. doi:10.1007/BF00236689
- Cecen, S., Niazi, I. K., Nedergaard, R. W., Cade, A., Allen, K., Holt, K., et al. (2018). Posture modulates the sensitivity of the H-reflex. *Experimental Brain Research*, *236*(3), 829–835. doi:10.1007/s00221-018-5182-x
- Chen, Y. S., & Zhou, S. (2011). Soleus H-reflex and its relation to static postural control. *Gait and Posture*, *33*(2), 169–178. doi:10.1016/j.gaitpost.2010.12.008
- Chen, Y. S., Zhou, S., Cartwright, C., Crowley, Z., Baglin, R., & Wang, F. (2010). Test-retest reliability of the soleus H-reflex is affected by joint positions and muscle force levels. *Journal of Electromyography and Kinesiology*, *20*(5), 980–987. doi:10.1016/j.jelekin.2009.11.003
- Colomer-Poveda, D., Romero-Arenas, S., Vera-Ibáñez, A., Viñuela-García, M., & Márquez, G. (2017). Effects of 4 weeks of low-load unilateral resistance training, with and without blood flow restriction, on strength, thickness, V wave, and H reflex of the soleus muscle in men. *European Journal of Applied Physiology*, *117*(7), 1339–1347.

doi:10.1007/s00421-017-3622-0

- De Lisa, J. A., & Brozovich, F. V. (1983). Volume conduction in electromyography: Experimental and theoretical review. *Electromyography and Clinical Neurophysiology*, 23(7), 651–673.
- Dijkhuizen, A., Douma, R. K., Krijnen, W. P., van der Schans, C. P., & Waninge, A. (2018). Measuring Quadriceps strength in adults with severe or moderate intellectual and visual disabilities : Feasibility and reliability. *Journal of Applied Research in Intellectual Disabilities*, 31(6), 1083–1090. doi:10.1111/jar.12468
- Earles, D. R., Koceja, D. M., & Shively, C. W. (2000). Environmental changes in soleus H-reflex excitability in young and elderly subjects. *International Journal of Neuroscience*, 105(1–4), 1–13. doi:10.3109/00207450009003261
- Espeit, L., Pavailler, S., & Lapole, T. (2017). Effects of compression stockings on ankle muscle H-reflexes during standing. *Muscle and Nerve*, 55(4), 596–598. doi:10.1002/mus.25455
- Galli, M., Cimolin, V., Condoluci, C., Pau, M., Leban, B., & Albertini, G. (2016). Foot-ground interaction during standing in individuals with down syndrome: A longitudinal retrospective study. *Journal of Developmental and Physical Disabilities*, 28(6), 835–847. doi:10.1007/s10882-016-9513-1
- Gerbino, P. G., Griffin, E. D., & Zurakowski, D. (2007). Comparison of standing balance between female collegiate dancers and soccer players. *Gait and Posture*, 26(4), 501–507. doi:10.1016/j.gaitpost.2006.11.205
- Goode, D. J., & Van Hoven, J. (1982). Loss of Patellar and Achilles Tendon Reflexes in Classical Ballet Dancers. *Archives of Neurology*, 39(5), 323. doi:10.1001/archneur.1982.00510170065030
- Gruber, M., Taube, W., Gollhofer, A., Beck, S., Amtage, F., & Schubert, M. (2007).

- Training-specific adaptations of H- and stretch reflexes in human soleus muscle. *Journal of Motor Behavior*, 39(1), 68–78. doi:10.3200/JMBR.39.1.68-78
- Guissard, N., & Duchateau, J. (2004). Effect of static stretch training on neural and mechanical properties of the human plantar-flexor muscles. *Muscle and Nerve*, 29(2), 248–255. doi:10.1002/mus.10549
- Gutiérrez-Vilahú, L., Massó-Ortigosa, N., Costa-Tutusaus, L., Guerra-Balic, M., & Rey-Abella, F. (2016). Effects of a dance program on static balance on a platform in Young Adults With Down Syndrome. *Adapted physical activity quarterly : APAQ*, 33, 233–252. doi:10.1123/apaq.2015-0048
- Gutierrez Rivas, E., Jimenez Hernández, M. D., Pardo Fernandez, J., & Romero Acebal, M. (2000). *Manual de electromiografía clínica* (Prous Scie.). Barcelona, Spain.
- Hopkins, J. T., Ingersoll, C. D., Cordova, M. L., & Edwards, J. E. (2000). Intrasession and intersession reliability of the Soleus H-reflex in supine and standing positions. *Electromyography and clinical neurophysiology*, 40(2), 89–94.
- Hortobágyi, T., van de Waardt, L. E., Tokuno, C. D., Taube, W., & Papegaaij, S. (2018). Age-related reversal of spinal excitability during anticipatory postural control. *European Journal of Applied Physiology*, 118(12), 2577–2585. doi:10.1007/s00421-018-3982-0
- Huang, T.-H., Chou, L.-W., Huang, C.-Y., Wei, S.-W., Tsai, Y.-J., & Chen, Y.-J. (2019). H-reflex in abductor hallucis and postural performance between flexible flatfoot and normal foot. *Physical Therapy in Sport*, 37(2019), 27–33. doi:10.1016/j.ptsp.2019.02.004
- Knikou, M. (2008). The H-reflex as a probe: Pathways and pitfalls. *Journal of Neuroscience Methods*, 171(1), 1–12. doi:10.1016/j.jneumeth.2008.02.012
- Koceja, D. M., Burke, J. R., & Kamen, G. (1991). Organization of segmental reflexes in trained dancers. *International Journal of Sports Medicine*, 12(3), 285–289.

doi:10.1055/s-2007-1024682

- König, N., Ferraro, M. G., Baur, H., Taylor, W. R., & Singh, N. B. (2017). What Is the Contribution of Ia-Afference for Regulating Motor Output Variability during Standing? *Frontiers in Human Neuroscience, 11*(March). doi:10.3389/fnhum.2017.00087
- Kumar, A., Soodan, J. S., Kumar, R., & Kaur, L. (2012). Comparison of H-Reflex Response of Sprinters & Non-Athletes. *Journal of Exercise Science and Physiotherapy, 8*(2), 63–66.
- Marchand-Pauvert, V., & Nielsen, J. B. (2002). Modulation of non-monosynaptic excitation from ankle dorsiflexor afferents to quadriceps motoneurons during human walking. *Journal of Physiology, 538*(2), 647–657. doi:10.1113/jphysiol.2001.012675
- Masgutova, S., Akhmatova, N., & Ludwika, S. (2016). Reflex Profile of Children with Down Syndrome Improvement of Neurosensorimotor Development Using the MNRI® Reflex Integration Program. *International Journal of Neurorehabilitation, 3*(1), 197. doi:10.4172/2376-0281.1000197
- Masgutova, S., Sadowska, L., Kowalewska, J., Masgutov, D., Akhmatova, N., & Filipowski, H. (2015). Use of a Neurosensorimotor Reflex Integration Program to Improve Reflex Patterns of Children with Down Syndrome. *Journal of Neurology and Neuroscience, 6*(4), 1–8. doi:10.21767/2171-6625.100059
- Massó-Ortigosa, N., Gutiérrez-Vilahú, L., Rey-Abella, F., Costa-Tutusaus, L., & Guerra-Balic, M. (2013). Analysis of centre of pressure in standing position in young subjects with Down Syndrome. *Journal of Sports Sciences, 24*(2), 178–181.
- Maulen Arroyo, J. H., Montecinos Espinoza, R. M., & Vargas Vitoria, C. R. (2000). El reflejo de Hoffman se modifica por efecto del entrenamiento físico aeróbico y anaeróbico. *Apunts.Medicina de l'Esport, 35*(134), 13–20. doi:10.1016/S1886-6581(00)75969-X

- Mynark, R. G., & Koceja, D. M. (1997). Comparison of soleus H-reflex gain from prone to standing in dancers and controls. *Electroencephalography and Clinical Neurophysiology*, *105*(2), 135–140. doi:10.1016/S0924-980X(96)96096-8
- Nielsen, J., Crone, C., & Hultborn, H. (1993). H-reflexes are smaller in dancers from The Royal Danish Ballet than in well-trained athletes. *European Journal of Applied Physiology and Occupational Physiology*, *66*(2), 116–121. doi:10.1007/BF01427051
- Park, T.-J. (2014). The Effects of Wobble Board Training on the Eyes Open and Closed Static Balance Ability of Adolescents with Down Syndrome. *Journal of Physical Therapy Science*, *26*(4), 625–627. doi:10.1589/jpts.26.625
- Perez, M. A., Lundbye-Jensen, J., & Nielsen, J. B. (2007). Task-specific depression of the soleus H-reflex after cocontraction training of antagonistic ankle muscles. *Journal of Neurophysiology*, *98*(6), 3677–3687. doi:10.1152/jn.00988.2007
- Pierrot-Deseilligny, E., & Mazevet, D. (2000). The monosynaptic reflex: A tool to investigate motor control in humans. Interest and limits. *Neurophysiologie Clinique*, *30*(2), 67–80. doi:10.1016/S0987-7053(00)00062-9
- Poh, E., Riek, S., & Carroll, T. J. (2013). Ipsilateral corticospinal responses to ballistic training are similar for various intensities and timings of TMS. *Acta Physiologica*, *207*(2), 385–396. doi:10.1111/apha.12032
- Rigoldi, C., Galli, M., & Albertini, G. (2011). Gait development during lifespan in subjects with Down syndrome. *Research in developmental disabilities*, *32*(1), 158–63. doi:10.1016/j.ridd.2010.09.009
- Rigoldi, C., Galli, M., Vimercati, S. L., Condoluci, C., Tacchino, G., Bianchi, A. M., & Albertini, G. (2016). Monosynaptic Reflexes and Preprogrammed Reactions in Down Syndrome: A Surface Electromyographic Study. *Journal of Policy and Practice in Intellectual Disabilities*, *13*(2), 157–164. doi:10.1111/jppi.12152

- Ryder, R., Kitano, K., & Koceja, D. M. (2010). Spinal reflex adaptation in dancers changes with body orientation and role of pre-synaptic inhibition. *Journal of Dance Medicine & Science, 14*(4), 155–162.
- Silva-Batista, C., de Oliveira Lira, J. L., David, F. J., Corcos, D. M., Tavares Mattos, E. C., Boari Coelho, D., et al. (2019). Short-term resistance training with instability reduces impairment in V wave and H reflex in individuals with Parkinson's disease. *Journal of Applied Physiology, 127*(1), 89–97. doi:10.1152/jappphysiol.00902.2018
- Spain. (2016). *Royal Decree Law 1971/1999 , December the 23th, procedure for recognition, declaration and qualification of the degree of disability*. http://www.seg-social.es/Internet_1/Normativa/097360
- Tokuno, C. D., Taube, W., & Cresswell, A. G. (2009). An enhanced level of motor cortical excitability during the control of human standing. *Acta Physiologica, 195*(3), 385–395. doi:10.1111/j.1748-1716.2008.01898.x
- Tomczak, M., & Tomczak, E. (2014). The need to report effect size estimates revisited. An overview of some recommended measures of effect size. *Trends in Sport Sciences, 1*(21), 19–25.
- Trimble, M. H., & Koceja, D. M. (2001). Effect of a reduced base of support in standing and balance training on the soleus H-reflex. *International Journal of Neuroscience, 106*(1), 1–20. doi:10.3109/00207450109149734
- Vila-Chã, C., Falla, D., Correia, M. V., & Farina, D. (2011). Changes in H reflex and V wave following short-term endurance and strength training. *Journal of Applied Physiology, 112*(1), 54–63. doi:10.1152/jappphysiol.00802.2011
- Villarroya, M. A., González-Agüero, A., Moros, T., Gómez-Trullén, E., & Casajús, J. A. (2013). Effects of whole body vibration training on balance in adolescents with and without Down syndrome. *Research in Developmental Disabilities, 34*(10), 3057–3065.

doi:10.1016/j.ridd.2013.06.015

Waninge, A., Van Wijck, R., Steenbergen, B., & Van der Schans, C. P. (2011). Feasibility and reliability of the modified Berg Balance Scale in persons with severe intellectual and visual disabilities. *Journal of intellectual disability research*, 55(3), 292–301.

doi:10.1111/j.1365-2788.2010.01358.x

Figure Captions

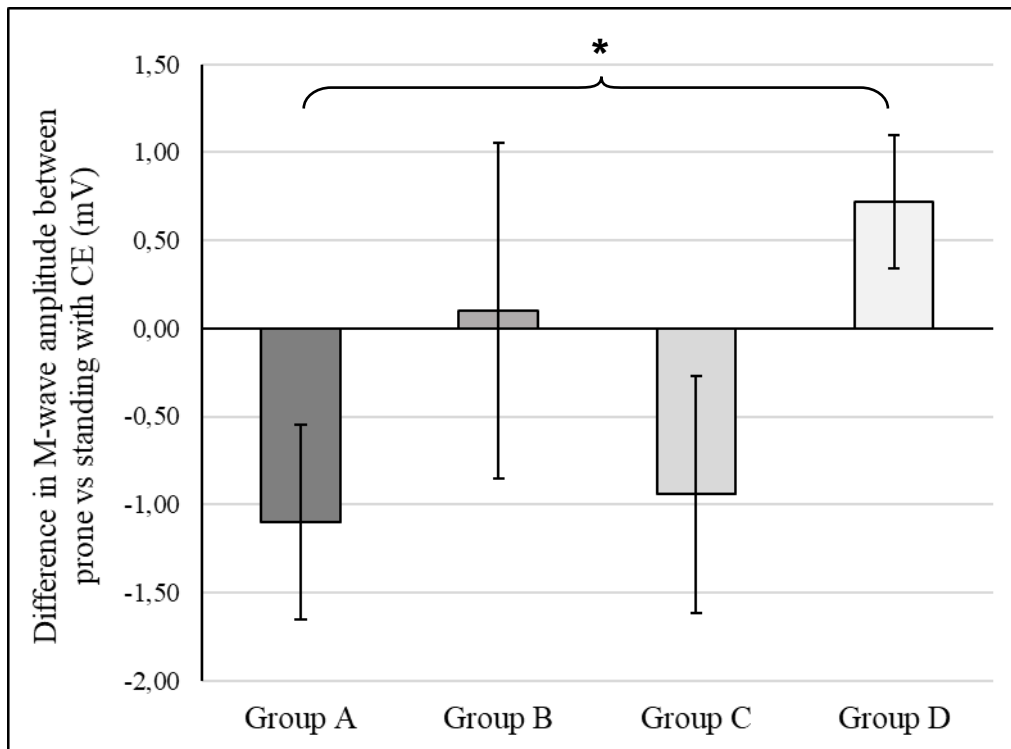


Figure 1. Difference in the M-wave amplitude at different conditions (prone decubitus position vs static standing position with CE). Abbreviations: CE (closed eyes). Values are means \pm standard error; $n = 5$ for group A; $n = 6$ for group B; $n = 7$ for group C; $n = 6$ for group D. * Significant difference between groups A vs D ($p = .028$).

Figure Captions

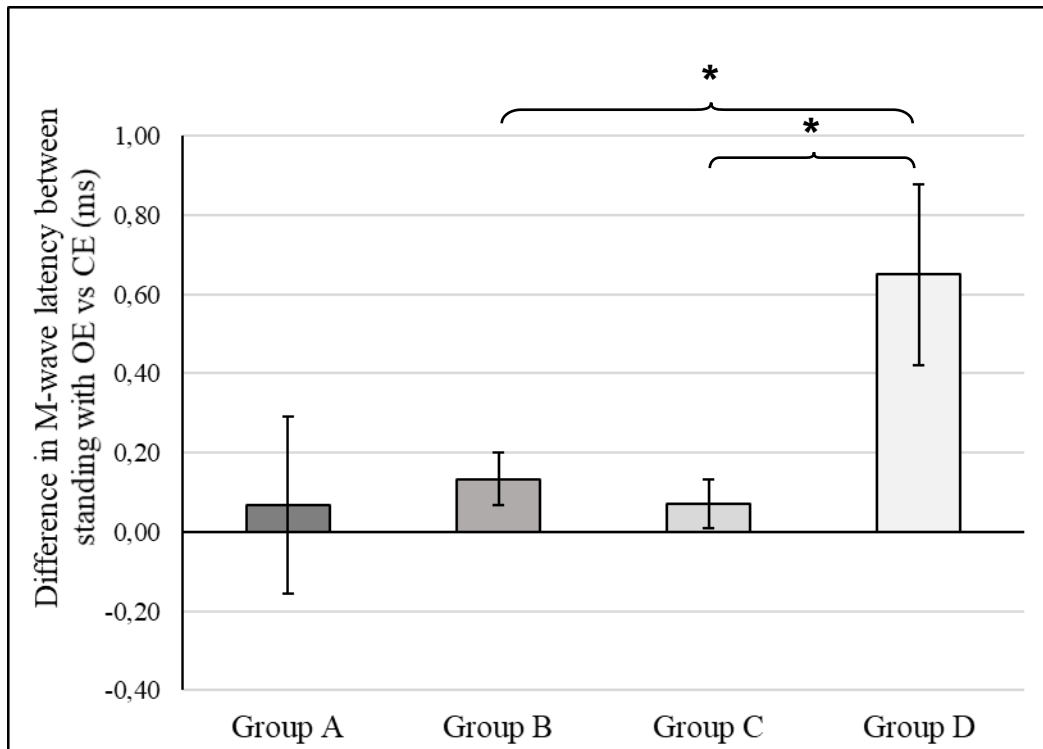


Figure 2. Difference in the M-wave latency at different conditions (static standing position with OE vs static standing position with CE). Abbreviations: OE (open eyes); CE (closed eyes). Values are means \pm standard error; $n = 5$ for group A; $n = 6$ for group B; $n = 7$ for group C; $n = 6$ for group D. * Significant difference between groups D vs B ($p < .033$) and D vs C ($p < .016$).

Table 1. Characteristics of the participants.

Characteristics	Group A (n=6)		Group B (n=6)		Group C (n=7)		Group D (n=6)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sex (M/F)	4/2	-	3/3	-	3/4	-	3/3	-
Age (y)	20.25	2.05	22.42	3.93	21.22	3.25	20.45	1.70
Weight (kg)	59.10	13.76	57.25	8.38	61.96	11.16	59.05	7.48
Height (cm)	160.50	10.37	153.83	13.59	169.07	7.60	168.42	6.38 *
BMI (kg/m ²)	22.97	4.81	24.53	4.99	21.49	2.25	20.72	1.13

Note: values are means \pm Standard Deviation. Abbreviations: BMI (body mass index).

* Significant difference between groups B vs C ($p = .045$).

Table 2. Within-groups H-reflex and M-waves comparisons at different conditions (prone decubitus position; static standing with OE and static standing with CE).

Variables	Prone Decubitus Position		Static Standing Position with OE		Static Standing Position with CE		<i>p</i> ₁	<i>p</i> ₂	<i>p</i> ₃
	Mean	SD	Mean	SD	Mean	SD			
Group A									
H-reflex latency (ms) ^{1;3}	26.30	1.24	27.70	-	-	-	-	-	-
M-wave latency (ms) ^{2;4}	3.99	0.36	3.90	0.36	3.83	0.42	.655	.785	.655
H-reflex amplitude (mV) ^{1;3}	2.02	0.47	3.10	-	-	-	-	-	-
M-wave amplitude (mV) ^{2;4}	2.10	0.58	3.27	1.52	3.10	0.95	.285	.180	.593
H-M latency (ms) ^{1;3}	22.30	1.21	23.70	-	-	-	-	-	-
H/M amplitude ratio ^{1;3}	1.03	0.30	0.63	-	-	-	-	-	-
Group B									
H-reflex latency (ms)	27.12	4.00	27.63	3.89	27.80	3.70	.599	.528	.833
M-wave latency (ms)	3.95	0.50	3.83	0.22	3.70	0.27	.588	.225	.102
H-reflex amplitude (mV)	1.32	0.98	0.92	0.87	0.99	0.89	.399	.600	1.00
M-wave amplitude (mV)	4.17	1.54	4.05	1.77	4.07	1.73	.686	.686	.317
H-M latency (ms)	23.17	3.61	23.80	3.79	24.10	3.52	.917	.600	.686
H/M amplitude ratio	0.31	0.16	0.19	0.16	0.21	0.17	.247	.463	.715
Group C									
H-reflex latency (ms)	28.80	1.66	28.11	1.87	28.06	1.93	.500	.462	.553
M-wave latency (ms)	3.43	1.14	3.18	0.98	3.11	1.01	.093	.042	.221
H-reflex amplitude (mV)	2.57	1.68	2.34	1.57	2.14	1.40	.735	.612	.496
M-wave amplitude (mV)	3.57	1.34	4.34	1.56	4.51	1.80	.249	.249	.686
H-M latency (ms)	25.37	1.94	24.93	1.99	24.94	2.13	.917	.799	.932
H/M amplitude ratio	0.72	0.45	0.55	0.31	0.59	0.51	.398	.499	.799
Group D									
H-reflex latency (ms) ⁵	28.62	1.20	29.30	-	28.70	-	-	-	-
M-wave latency (ms)	3.60	0.35	3.75	0.83	3.10	0.57	.686	.066	.027
H-reflex amplitude (mV) ⁵	1.62	1.10	0.60	-	1.60	-	-	-	-
M-wave amplitude (mV)	4.00	1.09	3.58	1.28	3.28	1.79	.465	.043	.465
H-M latency (ms) ⁵	25.02	1.06	26.80	-	26.70	-	-	-	-

H/M amplitude ratio ⁵	0.47	0.34	0.15	-	0.43	-	-	-	-
----------------------------------	------	------	------	---	------	---	---	---	---

Note: values are means ± Standard Deviation. Abbreviations: OE (opened eyes); CE (closed eyes).

*p*₁ prone decubitus position vs static standing position with OE; *p*₂ prone decubitus position vs static standing position with CE; *p*₃ static standing position with OE vs static standing CE.

Statistically significant values are showed in bold.

¹ n = 1 for group A in static standing OE

² n = 5 for group A in static standing OE.

³ n = 0 for group A in static standing CE.

⁴ n = 5 for group A in static standing CE.

⁵ n = 1 for group D in static standing OE and CE.

Table 3. Between-groups H-reflex and M-wave comparisons at different conditions (prone decubitus position; static standing with OE and static standing with CE).

Variable	Group A (n=7)		Group B (n=6)		Group C (n=7)		Group D (n=6)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Prone Decubitus Position									
H-reflex latency (ms)	26.30	1.24	27.12	4.00	28.80	1.66	28.62	1.20	**
M-wave latency (ms)	3.99	0.36	3.95	0.50	3.43	1.14	3.60	0.35	
H-reflex amplitude (mV)	2.02	0.47	1.32	0.98	2.57	1.68	1.62	1.10	
M-wave amplitude (mV)	2.10	0.58	4.17	1.54	3.57	1.34	4.00	1.09	*
H-M latency (ms)	22.30	1.21	23.17	3.61	25.37	1.94	25.02	1.06	**
H/M amplitude	1.03	0.30	0.31	0.16	0.72	0.45	0.47	0.34	***; †
Static Standing with OE									
H-reflex latency (ms) ^{1;4}	27.70	-	27.63	3.89	28.11	1.87	29.30	-	
M-wave latency (ms) ²	3.90	0.36	3.83	0.22	3.18	0.98	3.75	0.83	†
H-reflex amplitude (mV) ^{1;4}	3.10	-	0.92	0.87	2.34	1.57	0.60	-	
M-wave amplitude (mV) ²	3.27	1.52	4.05	1.77	4.34	1.56	3.58	1.28	
H-M latency (ms) ^{1;4}	23.70	-	23.80	3.79	24.93	1.99	26.80	-	
H/M amplitude ^{1;4}	0.63	-	0.19	0.16	0.55	0.31	0.15	-	†
Static Standing with CE									
H-reflex latency (ms) ^{3;4}	-	-	27.80	3.70	28.06	1.93	28.70	-	
M-wave latency (ms) ²	3.83	0.42	3.70	0.27	3.11	1.01	3.10	0.57	††
H-reflex amplitude (mV) ^{3;4}	-	-	0.99	0.89	2.14	1.40	1.60	-	
M-wave amplitude (mV) ²	3.10	0.95	4.07	1.73	4.51	1.80	3.28	1.79	
H-M latency (ms) ^{3;4}	-	-	24.10	3.52	24.94	2.13	26.70	-	
H/M amplitude ^{3;4}	-	-	0.21	0.17	0.59	0.51	0.43	-	

Note: values are means ± Standard Deviation. Abbreviations: OE (opened eyes); CE (closed eyes).

¹ n = 1 for group A. ² n = 5 for group A. ³ n = 0 for group A. ⁴ n = 1 for group D.

* Significant difference ($p < .050$) between groups A vs B; A vs C; A vs. D.

** Significant difference ($p < .050$) between groups A vs C; A vs. D.

*** Significant difference ($p < .050$) between groups A vs B; A vs. D.

† Significant difference ($p < .050$) between groups B vs C.

†† Significant difference ($p < .050$) between groups D vs A; D vs B.