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Research Article

Analysis of Heel Weight-Bearing Control Training in Individuals with Equine Foot Syndrome: Comparative Study on Different Ages Using Sensorial Biofeedback

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Abstract

Equine foot syndrome is a neurofunctional disorder that affects the ability to support the heel on the floor in upright stance or walking and performing the patterns of gait using the ankle movements (dorsiflexion and plantiflexion), in most hemiparetic individuals independent of the age. The aim of the study was to analyze the oscillation of weight-bearing on the heel of the paretic lower limb during sensorial motor training in hemiparetics volunteers. Two low-cost sensory feedback devices has been developed for capturing, through pressure sensors, the force applied on the posterior region of the feet in relation to the ground, and converting the information into intuitive and recreational audiovisual information at the system interface. Twenty hemiparetic volunteers, ages 10 to 83 years, performed 10 sessions of a motor training for applying weight on the heel using sensorial biofeedback device. The intuitive interface facilitates the learning and the ability to maintain the heel of the paretic leg in contact to the ground and maintaining the body balance during the accomplishment of the phases of the gait with the contralateral side. The results showed that the volunteers of the three groups increased the force applied on the heel during the tasks at the end of the ten sessions. The maximum variation reached was 1700 to 3500 gr./cm^2 with a gain variation of 19 to 39%, with an average value of 50 to 1600 gr./cm^2 (13% to 46%), signalizing an increase in bearing-weight gain at the end of the experiment. Regarding at the control of heel support stabilization during the motor task, the volunteers presented a negative variation of 100 to 700 gr./cm^2, with a variation of 13 to 39%, demonstrated by the analysis of the standard deviation of the mean values after experiment. The sensorial feedback system proved to be effective for providing body information, such as the proprioception and the motor learning.

Keywords: *Motor Learning; Equine Foot; Weight Bearing; Biofeedback*

Abbreviations

gr.: Grams; cm^2: Square Centimeter; R^2: Statistical Result; F: Fisher`s Statistic; SS: Sum of Squares; SM: Sum of Means; S. error: Standard Error

Introduction

The hemiparesis is characterized by decreased motor and sensory function on one side of the body by a cerebral vascular injury. The lack of "communication" between peripheral nerves and cortical areas affects the control of the contralateral cerebral hemisphere on the movements and perception. The cerebral vascular accident might be ischemic or hemorrhagic, due trauma, vascular and endocrine pathologies or vascular congenital deformities. So that, cortical lesions deactivate inhibitory axons in the spinal cord over some muscles, increasing the reflex of the movements (spasticity) and decreasing the capacity of co-contraction of the muscles, mainly the ankle`s muscles, difficulty the gait [1,2].

The beginning of gait movements and the consequent transition from upright stance to body displacement has two phases: 1) the postural phase, the preparation of the body for the trunk projection previously, in which all body weight, is applied at the heel, which initiates inhibition and facilitation of various muscles of the body. The body weight on lower limbs, more specifically in the heel, decrease the posterior inclination of the trunk initiating some motor patterns, inhibiting the soleus muscle isometric contraction and activating the anterior tibial muscle. The another transition phase, 2) oscillation phase, in which the contralateral lower limb is projected from the foot posterior position to the foot anterior position in relation to the body, promoting a great variation of the body balance and center of gravity for trunk stabilization [3,4]. The irregular medullar inhibitory pattern, by the subcortical injury, on ankle movements and muscles causes increase of the calf tonus (involuntary muscle contraction) promoting a small plantarflexion and removes the body support on the heel, keeping the forefoot in a supportive position. The foot position in a supported anterior region is known as "equine foot" syndrome (EFS) (Figure 1) [5-11].

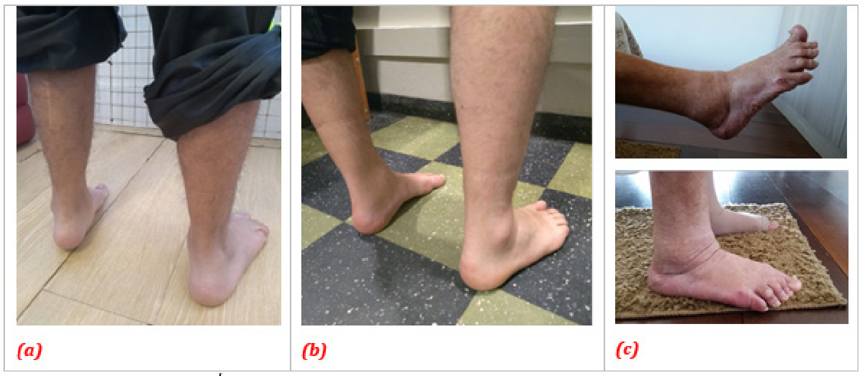

Figure 1: *Image of the feet with equine foot syndrome of three of the experiment volunteers. a. The image of feet of the seventeen years old volunteer with equinus foot of the left side after trauma brain injury. b. Image of the feet of the twenty six years old volunteer with paralyzed left side after trauma brain injury. c. Images of the feet of the seventy years old volunteer with right side paralyzed.*

For this reason, the heel is the main binding of the gait and the ground, and with the postural and neurophysiological corrections to keep the human being in upright standing and walk. The inhibition of the some muscles is important, inherent and necessary for changes in the coordination of the ankle movements, to assist the first step. Others usual methods are made to aid the gait by dorsiflexion and assist the individual to movement the ankle with equine foot, such as: drug ingestion, drug application and surgical procedures in the muscles. As well as, electrical stimulation and proprioceptive neuromuscular techniques, and manual stretching therapies [12-15].

Methodology

Sample

Twenty hemiparetic volunteers with EFS were selected to participate in the experiments, which were divided into two groups. The group 1 compose 10 individuals aged 10 - 18 years; eight had cerebral palsy after birth, one had cerebral palsy due to infectious encephalopathy in infancy and one post-traumatic brain injury. All volunteers were capable to understand instructions to perform such activities and tasks. The group 2 compose 5 individuals aged 18 - 52 years and the group 3 aged 52 - 89 years, as that, in the ten volunteers of group 2 and 3, eight individuals suffered "stroke", one subject with low cortical development, and one had traumatic brain injury (both group 2). All the 20 volunteers presented Ashworth`s scale level 1, which had difficulty supporting the heel of the foot on the paralyzed side during the withdrawal movement of the contralateral lower limb at the step.

Kinetic Biofeedback

The purpose of the experiment was to use two baropodometer devices; one wired device in which had an ease interface; numbers and sound to children and second device (wireless) had an computer intuitive interface; image, bars, colors and sound. Both devices storage data of the same form. All information from piezoelectric sensors; positioned in the rearfoot of the insole, insert into sandals, were registered in the SD card memory (wired device) and RAM memory computer (wireless device). The data were plotted on excel to know the maximum, minimum, and the average and standard deviation of the weight applied on heels.

The procedure accomplished had two stages: 1) asymmetrical position, which the volunteers was to train them to keep the body in upright stance, putting the paretic foot a feet forward as distance, and try to press the heel on the ground, aided by interface; and 2) symmetrical position, during the information from interface, to position itself correctly in the orthostatic position and during the step of the other lower limb, keeping the feet in parallel. In this way, the volunteers can control the balance of the trunk during changes of gait posture. At the beginning of the contralateral limb oscillation and support and the postural adjustment with the heels of the floor. From the training standard to balance training with kinetic biofeedback for twenty minutes and three times a week in ten sessions.

Data analysis

The volunteers performed the same task to learn how to apply weight on heel of the paretic foot using the insole with the sensors. The sensors provided values in grams per cm^2. Each training session, during the time of contralateral foot position change, provided a set of data from the peak of maximum, the mean and standard deviation values of the force applied on heels in each session, from all volunteers. For statistical analysis, it was obtained a mean value of the maximal, mean and standard deviation values ten sessions from each volunteers. The ANOVA and linear regression was made to know relationship between volunteers with 11 - 18 years old versus 18 - 52 years old (group 1), 11 - 18 yrs versus 52 - 89 yrs (group 2) and 18 - 52 yrs versus 52 - 89 yrs (group 3), after the 10 sessions with twenty minutes of training, three times per week. So, it was possible to perform to obtain the temporal correlation line between the mean values of the volunteers.

Results

The results of the study showed that all individuals, since younger volunteers until older volunteers were capable to use the device`s information; sound and image information, to keep support on heels on paretic lower limb during motor training after 10 sessions. Sensory and kinetic biofeedback showed efficacy to train the volunteers to stabilize the ability to apply heel force associated with the position changes of the lower limbs: from the asymmetrical position to the symmetrical position vice versa, keeping the weight-bearing on the paralyzed side.

The Graph of figure 2 shows the correlation of the mean values of the maximal, mean and standard deviation from the 10 sessions between the groups of 11 to 18 years and 18 to 52 years. The linear regression were plotted to analysis the temporal progression of the gain of the training. The coefficient of determination R^2 and the values of the adjustment of the variable are inserted within the graph in relation to its straight line.

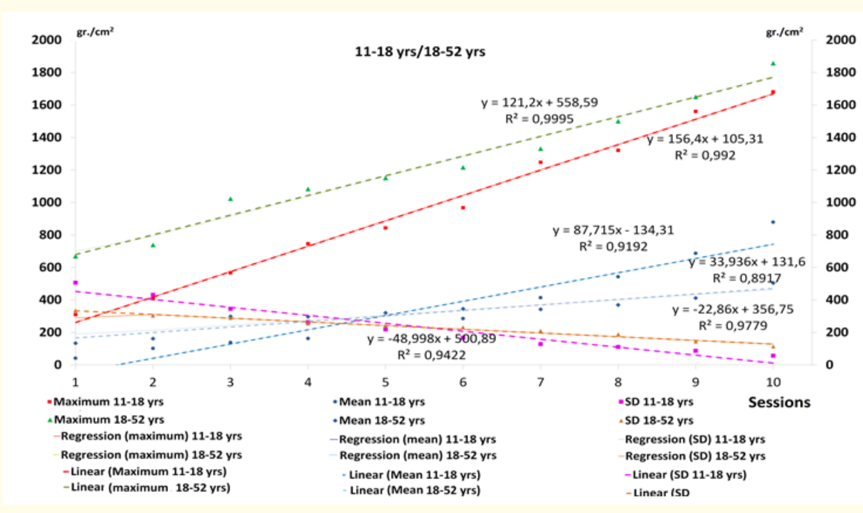

Figure 2: *The group 1 (11 - 18 yrs) - left scale (gr./cm²), red square (mean of maximum peak), red line and traces (linear regression of maximum peak), blue circle (mean values), blue lines and traces (linear regression of the mean values), pink square (Standard deviation of the mean values), pink lines and traces (linear regression of the standard deviation). The group 2 (18 - 52 yrs) - right scale (gr./cm²), green triangle (mean of maximum peak), green line and traces (linear regression of maximum peak), blue triangle (mean values), blue lines and traces (linear regression of the mean values), beige triangle (Standard deviation of the mean values), beige lines and traces (linear regression of the standard deviation).*

The Graph of figure 3 shows the correlation of the mean values of the maximal, mean and standard deviation from the 10 sessions between the groups of 11 to 18 years and 52 to 89 years. The linear regression were plotted to analysis the temporal progression of the gain of the training. The coefficient of determination R^2 and the values of the adjustment of the variable are inserted within the graph in relation to its straight line.

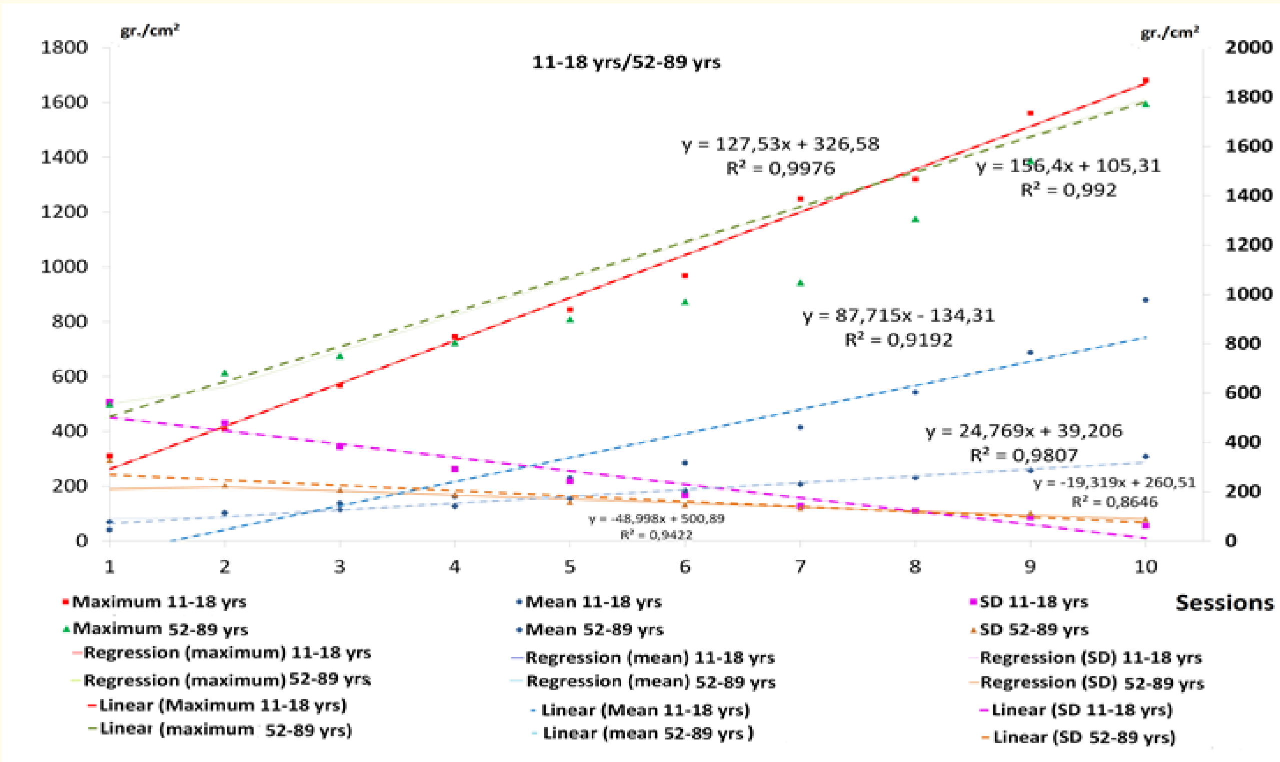

Figure 3: *The group 1 (11 - 18 yrs) - left scale (gr./cm²), red square (mean of maximum peak), red line and traces (linear regression of maximum peak), blue circle (mean values), blue lines and traces (linear regression of the mean values), pink square (Standard deviation of the mean values), pink lines and traces (linear regression of the standard deviation). The group 3 (52-89 yrs) - right scale (gr./cm²), green triangle (mean of maximum peak), green line and traces (linear regression of maximum peak), blue triangle (mean values), blue lines and traces (linear regression of the mean values), beige triangle (Standard deviation of the mean values), beige lines and traces (linear regression of the standard deviation).*

The graph of figure 4 shows the correlation of the mean values of the maximal, mean and standard deviation from the 10 sessions between the groups of 18 to 52 years and 52 to 89 years. The linear regression were plotted to analysis the temporal progression of the gain of the training. The coefficient of determination R^2 and the values of the adjustment of the variable are inserted within the graph in relation to its straight line.

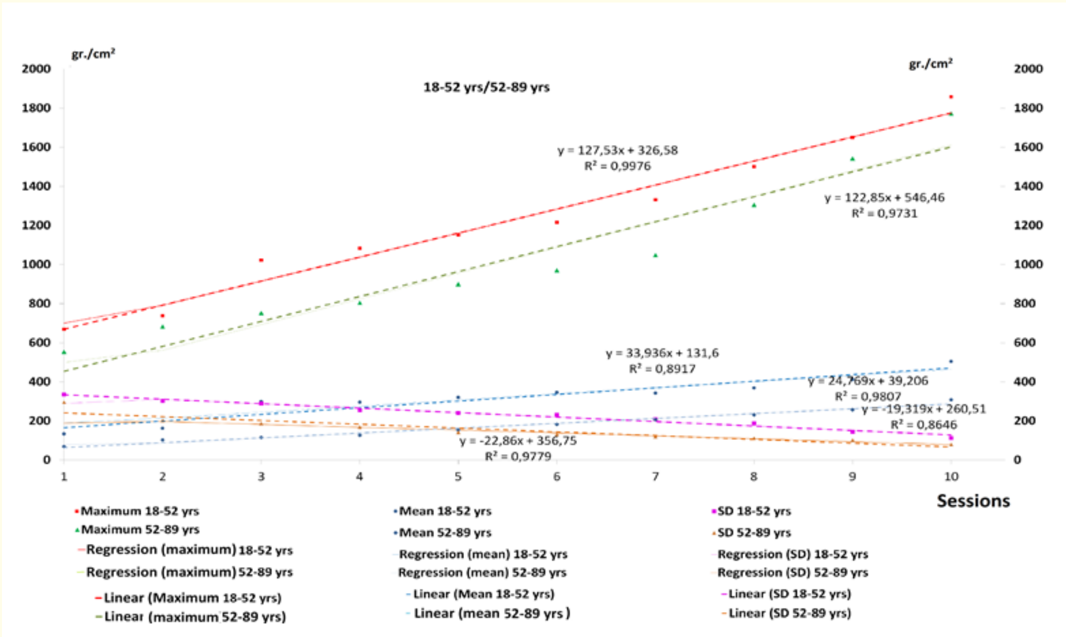

Figure 4: The group 2 (18 - 52 yrs) - left scale (gr./cm2), red square (mean of maximum peak), red line and traces (linear regression of maximum peak), blue circle (mean values), blue lines and traces (linear regression of the mean values), pink square(Standard deviation of the mean values), pink lines and traces (linear regression of the standard deviation). The group 3 (52 - 89 yrs) - right scale (gr./cm^2), green triangle (mean of maximum peak), green line and traces (linear regression of maximum peak), blue triangle (mean values), blue lines and traces (linear regression of the mean values), beige triangle (Standard deviation of the mean values), beige lines and traces (linear regression of the standard deviation).

Discussion

The study of the distance between of the center of mass and the paretic foot for weight-bearing training has been in the center of the small and complex inventions for recovering body balance and gait, through a simple apparatus for auditory feedback and balance scale or complex analysis of the heel support to gait training [16,17].

The graph shows that both groups of volunteers decreased the values of the standard deviation in relation to the mean and maximum values, evidencing the ability to control and sustain the increase in applied force, thereby decreasing the trunk oscillation during each session until the last session of the experiment.

The training protocol proposed by the experiment emphasizes the use of an intuitive apparatus through sensorial (audio-visual) stimulation to assist the patient with neuromuscular alteration that changes the movements of the lower limb, being voluntary with hemiparesis. According to Connell, Chambers, Mahboobin and Cham [18], the training of deceleration of the muscles of the lower limbs through the propulsion of the hip, especially in spastic muscles of the leg, prevent the effect of trunk imbalance during the gait oscillation phase in hemiparetic individuals.

The analysis of the data denote that relation among the ten sessions and the maximum values from group 1 show a R^2 adjusted of 0,991, S. error (45,08). In ANOVA regression with 1° of degree of freedom F = 992,97, f = 0,00 (< 0,05) and SS = 16258,47, SM 2032,3 to

8° of degrees of freedom from residue, angular coefficient variation of 156,39°, S. error (4,96) and T-statistical 31,51 p = 0,00 (p < 0,05), whereas for group 2 (18 - 52 years old|), R^2 adjusted of 0,958, S. error (70,11). In ANOVA regression with 1° of degree of freedom, F = 184,28 f = 0,00 (< 0,05) and SS = 34415,85 and SM 4916 for residue with 7° degrees of freedom, and an angular coefficient variation of 122,88°, S. error (9,05) T-statistical 13,575, p = 0,00 (p = 0,05).

The mean value from group 1 showed a R^2 adjusted of 0,909, S. error (83,515). In ANOVA regression with 1° degree of freedom F = 91,006, f = 0,00 (< 0,05) and SS = 55798, SM = 6974,8 for residue of 8° degrees of freedom, angular coefficient variation 87,715°, S. error (9,194) and T-statistical 9,539, p = 0,00 (p < 0,05). The group 2 showed a R^2 adjusted of 0,833, S. error (37,76). In ANOVA regression with 1° degree of freedom F = 41,147 f = 0,00 (< 0,00) and SS = 9985,6 and SM 1426,5 to 8° degrees of freedom, angular coefficient variation of 31,27°, S. error (4,87), T-statistical t = 6,414 and p = 0,00 (p < 0,05).

The standard deviation from group 1 showed a R^2 adjusted of 0,935, S. error (38,956). In ANOVA regression with 1° degree of freedom F = 130,52, f = 0,00 (< 0,05), SS = 12140, SM = 1517,5, angular coefficient variation -48,998°, S. error (4,288) and T-statistical -11,424 and p = 0,00 (p < 0,05). The group 2 showed a R^2 adjusted of 0,965, S. error (11,77). In ANOVA regression with 1° degree of freedom F = 223,14, f = 0,00 (< 0,05) and SS = 970,52 and SM = 138,65 for residue, angular coefficient variation of -22,71°, S. error (1,52) and T-statistical -14,94 and p = 0,00 (p < 0,05).

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The analysis of the data denote that relation among the ten sessions and the maximum values from group 2 showed a R^2 adjusted of 0,965, S. error (11,77). In ANOVA regression with 1° degree of freedom F = 223,14, f = 0,00 (< 0,05) and SS = 970,52 and SM = 138,65 for residue, angular coefficient variation of -22,71°, S. error (1,52) and T-statistical -14,94 and p = 0,00 (p < 0,05). Whereas for group 3 (18-89 years old|), R^2 adjusted of 0,903, S. error (116,73). In ANOVA regression with 1° of degree of freedom, F = 75,97 f = 0,00(< 0,05) e SS = 95389 and SM 13627,1 for residue with 7° of degree of freedom, angular coefficient variation of 131,35°, S. error (15,07) T-statistical 8,71 p = 0,00(p = 0,05).

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Conclusion

The results of the experiment showed that the volunteers had two important characteristics in relation to training with spastic paresis for weight-bearing gain. The weigh maximum applied on heel and the analysis of the standard deviation can aid futures developments of devices and techniques for gait training. Specially, games development and portable devices, as smart phones and tablets.

The age among volunteers showed a difference in timing learning in standard deviation direction for the adult's volunteers in comparison with the children and elderly, while the degree of spasticity did not present statistical difference among the volunteers.

Interesting Conflict

No conflict of interest.

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