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Original Article

Effect of whole-body vibration on abdominal thickness and sitting ability in children with spastic diplegia

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الملخص

أهداف البحث: يعتبر انخفاض كتلة العضلات والعظام، واختلال وظيفة العضلات، ودرجات متفاوتة من ضعف الحركة هي المضاعفات الرئيسة للشلل الدماغي. بالإضافة لذلك، يعاني عدد كبير من الأطفال المصابين بالشلل الدماغي من ضعف نشاط عضلات البطن. ويعد اهتزاز الجسم بالكامل أسلوبا فريدا لتعزيز القوة والقدرات الحركية في العديد من الحالات السريرية. ويهدف هذا البحث لتحديد تأثير تدخل اهتزاز الجسم بالكامل لمدة ١٢ أسبوعا على سماكة عضلات البطن والقدرة على الجلوس عند الأطفال المصابين بشلل مزدوج.

طرق البحث: تم اختيار ما مجموعه ٣٠ من الأطفال المصابين بالشلل الدماغي التشنجي (أعمارهم ٤-٦ سنوات) وتم تقسيمهم بشكل عشوائي إلى مجموعتين.تلقت مجموعة التحكم برنامج العلاج الطبيعي المختار لمدة ساعة واحدة، وتلقت المجموعة التجريبية تدريب الاهتزاز الكامل للجسم لمدة ١٠ دقائق بالإضافة إلى نفس برنامج العلاج الطبيعي المحدد والمقدم إلى مجموعة التحكم ٣ مرات/الأسبوع على مدار ١٢ أسبوعا. بعد ذلك، تم قياس سماكة عضلات البطن والقدرة على الجلوس باستخدام الموجات فوق الصوتية وقياس الوظيفة الحركية الإجمالية-٨٨ (مجال الجلوس).

النتائج: أظهرت قيم ما بعد العلاج تحسنا كبيرا في المتغيرات المقاسة لصالح المجموعة التجريبية، حيث كان هناك تحسنا في السماكة لأربعة من عضلات البطن بالمقارنة بمجموعة التحكم (عضلة الميلان الخارجي: القوة= ٧٨٣، ٣٨؛ عضلة الميلان الداخلي: القوة= ٥٤٧، ٩٩؛ عضلة البطن المستعرضة: القوة=٥٥٧، ١١١؛ وعضلة البطن المستقيمة: القوة=٩٤٠، ١٢٩). وكان هناك أيضا تحسنا كبيرا ملحوظا في قيم قياس الوظيفة الحركية الإجمالية-٨٨ بالمقارنة بمجموعة التحكم (القوة=٩٤٠، ١٢٩).

الاستنتاجات: يمكن أن يكون اهتزاز الجسم بالكامل استراتيجية قابلة للتطبيق لتحسين القدرة على الجلوس وسماكة عضلات البطن بين الأطفال المصابين بالشلل النصفي التشنجي.

الكلمات المفتاحية: سماكة البطن؛ الشلل الدماغي؛ الشلل المزدوج؛ القدرة على الجلوس؛ اهتزاز الجسم بالكامل.

Abstract

Objective: Reduced muscle and bone mass, improper muscle function, and varying degrees of mobility dysfunctions are the main complications of cerebral palsy (CP). Many children with CP also present with poor abdominal muscle activation. Whole-body vibration (WBV) is a unique approach for enhancing strength and motor abilities in several clinical conditions. This study aimed to determine the influence of a 12-week WBV intervention on the thickness of the abdominal muscles and the sitting ability of children with diplegia.

Methods: A total of 30 children with spastic diplegic CP (aged 4–6 years) were randomly divided into two groups (control and experimental). The control group received a selected physical therapy program for 1 h, and the study group received WBV training for 10 min in addition to the same selected program for the control group for 3 times/week over a period of 12 weeks. Thereafter, abdominal muscle thickness and sitting ability were measured using ultrasonography and the Gross Motor Function Measure-88 (GMFM-88, sitting domain).

Results: Post treatment values revealed significant improvement in the measured variables in favour of the experimental group ($p < 0.05$), as there was improvement in the thickness of the four abdominal muscles compared to the control group (external oblique: F = 38.783; internal oblique: F = 99.547; transverse abdominis:

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$F = 111.557$, and rectus abdominis: $F = 129.940$, $p < 0.05$). Additionally, the study group showed a significantly greater improvement in GMFM-88 values compared to the control group ($F = 129.940$, $p < 0.05$).

Conclusion: WBV can be a viable strategy for improving sitting ability and abdominal muscle thickness among children with spastic diplegia.

Keywords: Abdominal thickness; Cerebral palsy; Diplegia; Sitting ability; Whole-body vibration

Introduction

Cerebral palsy (CP) is the main cause of severe motor dysfunction during infancy,[1] affecting developmental milestones, especially sitting and walking, in most children. The principal treatment goals for children with CP include developing their ability to sit and walk, in addition to other functional abilities.[1] Poor postural control is the primary manifestation of motor dysfunction in children with spastic CP.[2]

Sitting is an essential motor milestone as it is the first instantiation of upright posture. Sitting postural control requires coordination between the trunk and pelvis, with the legs and buttocks as the base of support.[3]

The abdominal muscles, which consist of internal (IO) and external oblique (EO), the transverse abdominis (TA), and rectus abdominis (RA), are primarily responsible for postural stability and trunk stabilisation.[4] Accordingly, the TA may have a protective role during activity that challenges the integrity of the lumbar spine. Several reports have suggested that the TA plays a greater role in increasing spinal stability compared to other muscles.[5] The lateral abdominal muscles, including TA, IO, and EO, provide stability to the trunk through different functional activities. Thus, assessing the size and thickness of the abdominal muscles is essential during trunk training and balance.[6]

Skeletal muscles have significant plasticity and can rapidly gain or lose contractile ability according to the loading routine. Therapists have directly[7] or indirectly[8] emphasised the role of the abdominal muscles in improving motor function and postural control. Improving trunk control and abdominal muscle strength is usually recommended for diplegic children with anterior tilting of the pelvis.[9,7] An anterior pelvic tilt promotes prolonged stretching of the TA and RA, which inhibits the stretch reflex and maintains a neutral pelvis.[10]

Strengthening programs may be beneficial for bone growth and motor function enhancement in children with CP. Accordingly, whole-body vibration (WBV) is one strategy for improving muscle strength that is applicable across a wide range of practical areas.[11,12] Other studies have established that WBV increases bone mineral density.[13] WBV is performed with the child sitting in a static position on a device. Although each abdominal muscle works individually and has primary stabilising and motor functions, proficient stability and movement of the trunk requires accumulated exertion of the trunk musculature.[14,15]

Studies have shown that WBV increases strength, enhances functional performance, and reduces spasticity, subsequently increasing the mobility of children with CP.[16] Reduced muscle mass is another common disorder affecting children with CP.[17] Accordingly, ultrasonography, a non-invasive approach for measuring muscle thickness during resting state and stimulation,[18] can be utilised to determine the muscle architecture of children with spastic CP.[19,20]

Several studies have utilised the influence of WBV to strengthen muscles and improve walking ability in children with CP.[21,22] WBV's success in activating the musculoskeletal system is considered an encouraging approach to increasing muscle strength, walking ability and enhancement of gross motor function in such children.[23,24] The current study is a novel attempt at determining the role of WBV on abdominal muscle thickness, which reflects on sitting ability and trunk control in children with diplegia. Accordingly, we hypothesised that WBV would improve sitting ability and increase abdominal muscle thickness in children with diplegia, thereby improving posture and the activities of daily living.

Materials and Methods

Participants

A total of 31 children with spastic diplegia (mean age: study group, 4.87 ± 0.67 years; control group, 5.23 ± 0.70 years) were recruited from the outpatient clinic of the faculty of physical therapy at Cairo university. One child from the study group dropped out during treatment due to his family travelling out of the country, as shown in Figure 1. None of the patients underwent a vibration program within the last 6 months. The degree of spasticity was 1 and 1+ according to the Modified Ashworth Scale.[25] The functional level was assessed using the Gross Motor Function Classification Scale,[26] with only children at levels I–IV included. Those who received medical treatment directly affecting muscular function, such as Botulinum toxin injection, surgical intervention, and casting less than 6 months before the study were excluded. Children with obesity (body mass index > 25 kgm^{-2}) were also excluded as exorbitant amounts of adipose tissue impede the ability of ultrasonography to detect muscle thickness.[27]

Randomisation

Simple randomisation was performed using a computer-generated randomised table, created using the Statistical Package for Social Sciences (SPSS), and prepared ahead of data collection. A specific identification number was allocated to every participant, which indicated the group to which they would be allocated. Individual and sequentially numbered index cards were secured in opaque envelopes. Each participant was given a hand-picked envelope and was relocated accordingly to their groups. The children's parents received an explanation regarding the study's aim and procedures. The children were recruited from the clinic and randomised into two groups. The control group received physical a therapy program, while the study group received WBV in addition to the same physical therapy program, for a period of 12 weeks.

Sample size

Based on RA thickness data from the pilot study conducted on five subjects in each group, sample size calculation was performed using G*POWER statistical software (version 3.1.9.2), with $\alpha = 0.05$, power 80% and effect size = 1.1. The appropriate sample size for this study was determined as $N = 15$ in each group. Post hoc analysis with a sample size of 15 in each group revealed that the power of the study was 98%.

Procedures

Ultrasonography

An ultrasound transducer probe (7.5 MHz) was utilised to measure RA, IO, EO, and TA thickness. The main investigator held the transducer head (ultrasound probe), while the assistant provided instructions to the children. The probe was placed 2 or 3 cm away from the midline, with the umbilicus as a landmark, and subsequently moved in a circular manner until an image of the TA − the deepest muscle − was observed on the screen. Thereafter, a skin marker pen was used to indicate the position at which thickness would be measured. The probe was then moved in an oblique manner to determine EO, IO, and RA thickness. Ample probe pressure and lubricant gel were applied to obtain optimal muscle thickness values. Images were stored and analysed, measuring the length of a perpendicular line drawn between the deep and superficial aponeurosis. Measurements were performed three times, at different areas along the muscle length, until a clear image appeared, with the average measurement being recorded. Both groups underwent measurements before and after the intervention program.

Gross motor function measurement-88

Sitting ability was assessed using the sitting domain of the Gross Motor Function Measurement-88 (GMFM-88), a standard measurement tool for evaluating children with CP[28] that includes 88 items divided into five dimensions: lying and rolling, sitting, crawling and kneeling, standing and walking, and running and jumping. The GMFM-88 allows for the quantitative evaluation of children's gross motor function. The score for the sitting dimension is presented as a percentage of the maximum score for that dimension.

Intervention

Control group

For 1 h/3 times/week over 12 weeks, 15 children received a designed physiotherapy program that included neurodevelopmental techniques (righting and equilibrium reaction training) to improve the postural mechanism via a variety of exercises applied using a medical ball and roll at different positions, including training of protective reactions to prevent the child from falling over when balance was severely disturbed; balance and vestibular exercises; facilitation of postural reaction; facilitation of delayed milestones, especially standing and weight shifting; and balancing from different directions using a balance board and stretching exercises.

Study group

A total of 15 children received a WBV program for 10 min, in addition to the same designed-physiotherapy program.

Procedures for WBV training

The children were asked to squat on the platform and maintain their position for vibration training at a frequency of 30 Hz and an amplitude of 2 mm for 5 min, recording any distress arising therefrom. After 5 min, the vibration turned off automatically for 1 min. The children were then asked to stand on the vibration platform with support for 5 min using the same parameters mentioned previously. Overall, the training time during each practical session was 10 min.

Data analysis

Results are presented as mean ± standard deviation. Comparisons between categorical data [number (%)] were performed using the Chi-square test or Fisher's exact test when the cell count was less than five. The Kolmogorov−Smirnov normality test was used to measure the distribution of data before treatment. Accordingly, comparisons between normally distributed variables in both groups were performed using the unpaired t-test. Analysis of covariance (ANCOVA) was used to compare the post-treatment values between both groups, with pre-treatment values as covariates. The paired t-test was used to compare measurable variables before and after intervention within the same group. All data analyses were performed using SPSS (version 19 windows), with a P value ≤ 0.05 indicating statistical significance.

Results

No significant differences in demographic characteristics (mean age, $P = 0.154$; sex. $P = 0.713$) were observed between both groups ($P \geq 0.05$) (Table 1). Moreover, no significant differences in abdominal muscle thickness and motor function were observed between both groups before the intervention.

The mean pre-treatment abdominal muscle thickness values in both groups (control and study) were 0.35 ± 0.07 and 0.32 ± 0.04 for EO, 0.48 ± 0.04 and 0.46 ± 0.03 for IO, 0.32 ± 0.05 and 0.31 ± 0.03 for TA, and 0.68 ± 0.05 and 0.67 ± 0.03 for RA, respectively; comparisons of which indicated no significant difference ($P < 0.05$; Table 2).

Mean differences and percent changes in abdominal muscle thickness after treatment for the control group were 0.02 and 5.71% (EO), 0.03 and 6.25% (IO), 0.03 and 9.37%

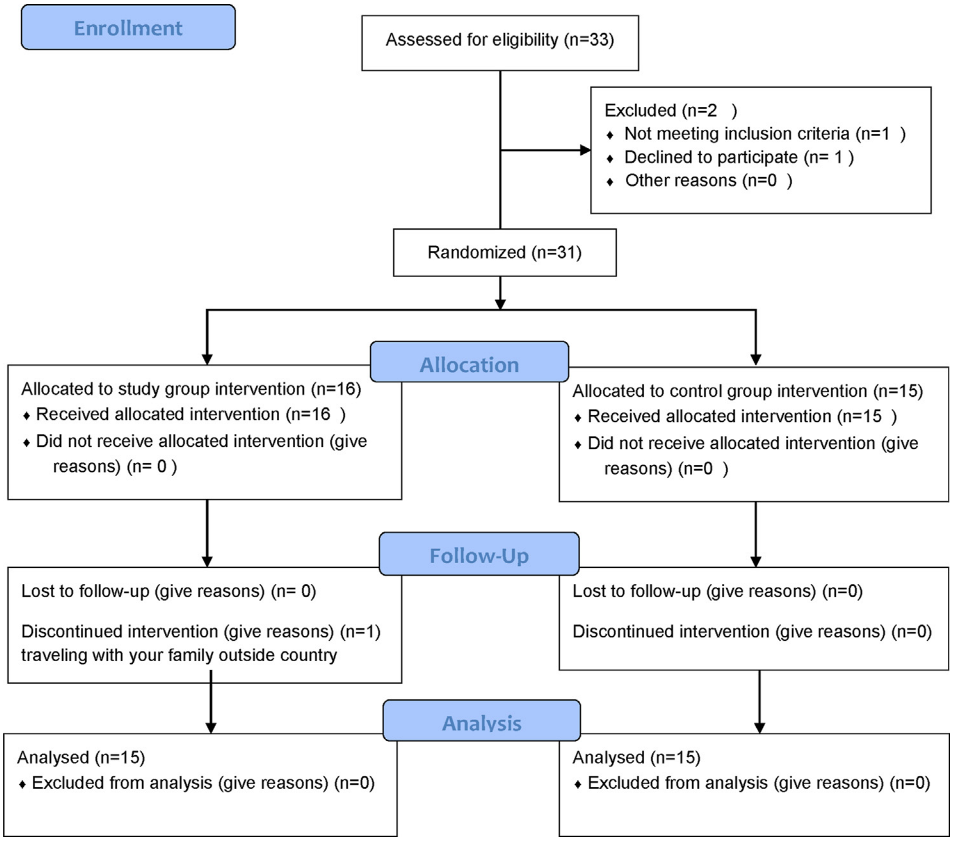

Figure 1: Flowchart of patient randomisation.

(TA), and 0.03 and 4.41% (RA). Accordingly, significant differences between the mean pre- and post-treatment abdominal muscle thickness values were noted ($P < 0.05$). The percent changes indicated post-treatment improvement in the control group, as shown in Table 2.

Moreover, the mean pre- and post-treatment differences and percent changes in abdominal muscle thickness in the study group were 0.10 and 31.25% (EO), 0.08 and 17.39% (IO), 0.09 and 29.03% (TA), and 0.100 and 14.93% (RA). Accordingly, significant differences between the mean pre- and post-treatment abdominal muscle thickness values were noted ($P < 0.05$). The percent changes are shown in Table 2.

After the intervention, ANCOVA showed that the study group exhibited significantly greater improvements in the thickness of the four abdominal muscles compared to the control group (EO: $F = 38.783$, $p = 0.001$; IO: $F = 99.547$, $p = 0.001$; TA: $F = 111.557$, $p = 0.001$, and RA: $F = 129.940$, $P = 0.001$) ($P < 0.05$) (Table 2).

The mean pre-treatment GMFM-88 values were 48.01 ± 8.55 and 46.04 ± 5.84 for the control and study groups, respectively; a comparison of which indicated no significant difference ($P < 0.05$; Table 3).

The mean pre- and post-treatment difference in GMFM-88 value in the control group was 5.02. Accordingly, a significant difference between mean pre- and post-treatment GMFM-88 values was observed ($P < 0.05$). The percent changes indicated post-treatment improvement, as shown in Table 3.

Moreover, the mean pre- and post-treatment difference and percent change in GMFM-88 were 13.54 and 29.41%, respectively. Accordingly, a significant difference between pre- and post-treatment GMFM-88 values was observed ($P < 0.05$). The percent change is presented shown in Table 3.

Table 1: Demographic characteristics of both groups.

	Control group (n = 15)	Study group (n = 15)	t value	P value
Age (years)	5.23 ± 0.70	4.87 ± ± 0.67	1.464	0.154 (NS)
Sex				
Girls	7 (46.7%)	6 (40.0%)	$\chi^2 = 0.136$	0.713 (NS)
Boys	8 (53.3%)	9 (60.0%)		

Data are expressed as mean ± SD or number (%). χ^2, Chi-square test; NS ($P > 0.05$), not significant.

Table 2: Comparison of mean abdominal muscle thickness values between both groups (pre- and post-treatment).

	Control group (n = 15)	Study group (n = 15)	F value	Cohen Effect size	P value
EO					
Pre-treatment	0.35 ± 0.07	0.32 ± 0.04	1.248	0.52	0.273 (NS)
Post-treatment	0.37 ± 0.07	0.42 ± 0.04	38.783	0.87	0.001 (S)
MD & % change	0.02 & 5.71% ↑↑	0.10 & 31.25% ↑↑			
Cohen Effect size	0.45	2.5			
t & p values	−2.346 & 0.034 (S)	−15.178 & 0.001 (S)			
IO					
Pre-treatment	0.48 ± 0.04	0.46 ± 0.03	2.347	0.56	0.137 (NS)
Post-treatment	0.51 ± 0.04	0.54 ± 0.03	99.547	0.84	0.001 (S)
MD & % change	0.03 & 6.25 ↑↑	0.08 & 17.39 ↑↑			
Cohen Effect size	0.75	2.66			
t & p values	−17.748 & 0.001 (S)	−18.558 & 0.001 (S)			
TA					
Pre-treatment	0.32 ± 0.05	0.31 ± 0.03	0.085	0.24	0.773 (NS)
Post-treatment	0.35 ± 0.04	0.40 ± 0.02	111.557	1.58	0.001 (S)
MD & % change	0.03 & 9.37 ↑↑	0.09 & 29.03 ↑↑			
Cohen Effect size	0.65	3.4			
t & p values	−21.313 & 0.001 (S)	−15.781 & 0.001 (S)			
RA					
Pre-treatment	0.68 ± 0.05	0.67 ± 0.03	0.038	0.24	0.846 (NS)
Post-treatment	0.71 ± 0.05	0.77 ± 0.02	129.940	1.42	0.001 (S)
MD & % change	0.03 & 4.41 ↑↑	0.100 & 14.93 ↑↑			
Cohen Effect size	0.6	3.77			
t & p values	−15.838 & 0.001 (S)	−19.571 & 0.001 (S)			

Data are expressed as mean ± SD.
MD, mean difference; F value, ANCOVA test; t value, paired t-test; NS ($P > 0.05$), not significant; S ($P < 0.05$), significant.

Table 3: Comparison between the mean values of sitting domain and GMFM-88 in both groups (pre- and post-treatment).

	Control group (n = 15)	Study group (n = 15)	F value	Cohen Effect size	P value
Pre-treatment	48.01 ± 8.55	46.04 ± 5.84	0.038	0.26	0.846 (NS)
Post-treatment	53.03 ± 4.98	59.58 ± 3.04	129.940	1.58	0.001 (S)
Mean difference	5.02	13.54			
% change	10.46 ↑↑	29.41 ↑↑			
Cohen Effect size	0.67	2.67			
$t^{\#\#}$ value	−3.700	−11.430			
p value	0.002 (S)	0.001 (S)			

Data are expressed as mean ± SD.
F value, ANCOVA test; t value, paired t-test; NS ($P > 0.05$), not significant; S, ($P < 0.05$), significant.

The study group exhibited a significantly greater improvement in GMFM-88 values compared to the control group ($F = 129.940$, $p = 0.001$) ($P < 0.05$; Table 3).

Discussion

The present study aimed to determine the effect of WBV on abdominal muscle thickness and sitting ability in children with spastic diplegia. Accordingly, our results revealed significant improvements in abdominal muscle thickness and sitting ability in both groups, with the study group experiencing slightly greater improvements. The results also revealed a large effect size within the variable which maximises the effect of WBV on the functional ability of children with spastic diplegia.

The current study confirms that the abdominal muscles can be strengthened in children with spastic diplegia. The stated increase in abdominal muscle thickness after treatment suggested changes in strength, which allowed for improved gross motor function in these children. We believe that the significant improvement in the sitting domain of the GMFM-88 occurred simultaneously with the increase in muscle thickness, given that an increase in muscle mass can improve child posture and development. Moreover, these results support the efficacy of 12 weeks of WBV intervention strengthened the abdominal muscles in children with spastic diplegia, thereby improving strength and posture.

The improvement observed in both groups may be attributed to the effects of the designed program that included facilitation of sitting, standing, and equilibrium, which supports and stimulates the abdominal muscles and enhances gross motor function. These results are consistent with those of Bobath[29] and Veerle et al.[30] who suggested that more strengthening of the trunk muscle after a regular physical therapy program may have been the primary reason for the improvement in motor function and strength in both groups.

Ali et al.[31] reinforced our results using side-to-side, alternating type WBV, with a frequency of 30 Hz and an amplitude of 2 mm. The stimulation was administered for 5 min in a squat sitting position on a platform, followed by rest for 1 min, then 5 min of vibration with standing on a platform using the same parameters of the current study. Ali et al. suggested that the strengthening of the trunk and lower-limb muscles occurred through WBV, achieving functional improvement in these children. Ahlborg et al.[16] further reinforced our results, utilising WBV at a frequency of 25–40 Hz for 10 min, three times a week for 3 months, in children with CP. Their results showed greater improvement of motor performance, including postural stability and trunk rotation, which improved the selectivity of movement in children with CP.

The greater improvement observed in the study group might have been related to the WBV application. For example, Unger et al.[32] reported that 4 weeks of WBV and physiotherapy promoted a greater increase in the thickness of four abdominal muscles at the resting state in 27 children, compared to physiotherapy alone.[31] Reduced motor function[33,34] has been a common problem among children with CP due to cerebral lesions that later limit regular movement, causing insufficient stimuli for muscle and bone growth.[35,36]

Considering the observed increase in abdominal muscle thickness at the resting state using ultrasonography, we hypothesised that changes in strength could have been accompanied by changes in muscle size.[37] Our results were consistent with those of Bogaerts et al.[38] who reported that WBV training had positive effects on power development and muscle strength, thereby enhancing motor function.[38] Moreover, the aforementioned results were consistent with those presented in previous studies showing that WBV (once a week for 3 months, at a frequency of 40 Hz for 20 min) in children with cerebral injury significantly enhances motor function, facilitated rotations, and improved postural stability and selectivity of movements in children with spastic CP.[39]

Furthermore, the increase in abdominal muscle thickness and improvement in motor function observed in the study group after WBV application might be due to the stimulation of proprioceptive spinal circuits, causing muscle contractions in the trunk and lower limbs.[40] The present study concluded that WBV increases abdominal muscle strength and consequently muscle mass, which was consistent with Cawthon et al.[41] who found a strong correlation between muscle strength and lean mass. Therefore, WBV can have a positive effect on muscle mass.[41] The outcomes of the current study confirm that abdominal muscles can be strengthened in children with spastic diplegia.[42]

The increase in abdominal muscle thickness after intervention suggests that an increase in abdominal muscle thickness at a morphological level can increase strength. The significant increase in body mass was assumed to be a result of the increase in muscle thickness and consequently muscle mass.[42] Moreover, WBV and the designed physiotherapy program seemingly effected the enhancement in motor function shown in the study group. Thus, it appears that the WBV program increased trunk and lower limb strength, ultimately improving functional ability in children with spastic CP.[43,44]

The improvement in the sitting domain (dimension C) of the GMFM-88 after 12 weeks of intervention was consistent with the results of Ahlborg et al.,[16] who reported that 8 weeks of WBV application promoted greater improvement in the D (standing) and E (walking, running, and jumping) dimensions compared to resistance training among children with diplegic CP.[16] Growth, especially in musculoskeletal tissues, requires mechanical forces acting on the body (WBV). Therefore, the substantial myogenic and osteogenic stimuli provided by WBV training may lead to muscle hypertrophy[45–47] and increased bone mineral density and bone mineral content.[45,47–50]

Finally, the results of the current study suggest that using WBV at a frequency of 30 Hz and an amplitude of 2 mm, in addition to a physical therapy program, may be a better option for improving abdominal muscle thickness.

Study limitations

One limitation of the current study was its small sample size to generalise the data measured.

Conclusion

The present study showed significant improvement in sitting ability and abdominal thickness in both the study and control groups, due to increased strengthening of the trunk muscles after a regular physical therapy program that included the facilitation of sitting, standing, and equilibrium. WBV can efficiently increase abdominal muscle thickness and improve gross motor function in children with diplegic CP, suggesting WBV as a useful intervention for improving abdominal muscle function and enhancing the activities of daily living for children with diplegic CP.

Recommendations

This study shows that WBV can aid in increasing abdominal muscle thickness and improving motor function in children with diplegic CP. Thus, WBV is recommended as part of a rehabilitation program for such children. This study's results can help individuals with CP who have trunk control problems (who need core stability) or to improve postural control and balance.

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Conflict of interest

The authors have no conflicts of interest to declare.

Ethical approval

This study was approved by the Ethical Committee faculty of physical therapy, Cairo University (NO:P.T.REC/012/002551) on 1 December 2019.

Authors contributions

MSM conceived and designed the study, conducted research, provided research materials, and collected and organised the data. HGA analysed and interpreted data, wrote the initial and final drafts of the article and provided logistic support. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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