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Original Article

Trunk-oriented Exercises Versus Whole-body Vibration on Abdominal Thickness and Balance in Children with Duchene Muscular Dystrophy

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Abstract

Objectives: Progressive proximal muscle weakening in children with Duchenne muscular dystrophy (DMD) impairs postural adjustments by impairing motor function and preventing ambulation. During daily activities, for gait and dynamic balance, certain postural modifications are required. The objective was to compare the impact of trunk-oriented exercises versus whole-body vibration on abdominal muscle thickness and balance in children with DMD. **Methods**: Participants in this study were 30 boys with DMD, aged 6 to 10 years old. Children were divided into two groups (A and B) randomly. Children in group (A) underwent a prescribed regimen of physical therapy along with trunk-oriented exercises, whereas group (B) received the same regimen as group (A) together with whole-body vibration three times per week for three consecutive months. Balance and the thickness of the abdominal muscles were measured using the Biodex balance system and ultrasonography, respectively, before and after therapy. **Results**: When compared to the pre-treatment results in both groups, the post-treatment results showed a significant difference in all measured variables ($p<0.05$). Post-treatment values showed that all of the measured variables significantly differed in favor of group A. **Conclusions**: Trunk-oriented exercises can improve abdominal thickness and balance more effectively than whole-body vibration in children with DMD. ClinicalTrials.gov ID: NCT05688072.

Keywords: Abdominal Thickness, Balance, Duchene Muscular Dystrophy, Stability Exercise, Whole-body Vibration

Introduction

The most prevalent kind of muscular dystrophy in children is Duchenne muscular dystrophy (DMD)[1]. The disorder makes up 85% of muscular dystrophies and leads to functional loss due to structural deterioration of the dystrophin protein that provides the connection in the muscle's cell membrane following deletions, duplications, or point mutations in the dystrophin gene located in the Xp21.2 regions[1,2]. Progressive proximal muscle weakening is the primary symptom of DMD, which also causes loss of ambulation[3], scoliosis, and decreased pulmonary function[4,5].

Children with DMD experience growing muscle weakness and contractures, which impair body balance by impairing the locomotor system[6]. The deterioration of balance in these children can reduce their functional capacity by restricting their movement, independence, and social interaction out of fear of falling[7]. Additionally, as a child ages, the trunk gradually becomes weaker, which may be related to upper- and lower-limb movement dysfunction. Daily tasks involving the use of the upper limbs become increasingly difficult as the ability of trunk muscles to regulate the upper body segments declines[8]. So any rehabilitation program for those children must include exercises that help to improve balance and trunk control.

The current treatment approaches, published in Standards of Care for DMD, are mainly symptomatic[2,9], aimed to

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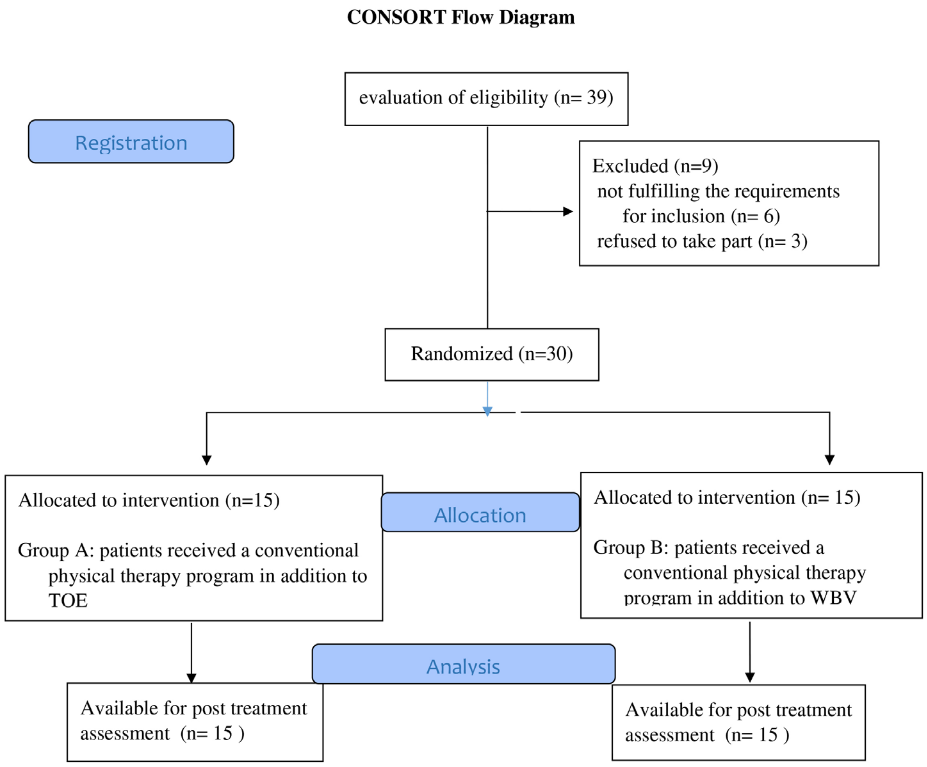

Figure 1. Patient randomization flowchart.

decelerate muscle atrophy, prevent contractures, and optimize muscle strength and coordination, with the goal of maximizing functional mobility and overall quality of life[10]. A therapeutic approach utilized in sports, rehabilitation, and preventative health is whole-body vibration training (WBVT)[11]. The patient engages in light physical activities while standing on a vibrating platform as part of the training[12]. The musculoskeletal system receives mechanical vibration from the vibrating platform, changing the length of the muscles[13]. The ensuing stimulation of muscle spindles causes the corresponding muscle to contract reflexively. Therefore, the vibratory stimulus causes cyclic elongation and contraction of the stimulated muscles[14], which results in an increase in bone mineral density[15-17], flexibility[16], and muscle strength[18]. The previous study reported that the use of WBV exercise has proven to be safe and could be effective in the rehabilitation of DMD to change muscle length and strength as a well-tolerated exercise modality[12]. As an alternative, trunk-oriented exercises (TOE) are a type of rehabilitation program exercise that helps patients improve their trunk control, which is in charge of adaptation during weight transfers, provides and maintains the upright position of the body, organizes postural and correction reactions, and stabilizes the body to perform proximal and distal limb movements, trunk rotations, and making contact between the shoulder and pelvis[19]. Many daily tasks, including walking, eating, writing, and climbing and descending stairs, require trunk control[20].

Knowing how well TOE and WBV impact balance and the thickness of the abdominal muscles allows physiotherapists to decide which of these two modalities will be most beneficial in a rehabilitation program designed for children with DMD. So, this study compared the effects of TOE and WBV on balance and abdominal muscle thickness in children with DMD.

The authors hypothesize that there was no difference between the effect of TOE and whole-body vibration on abdominal muscle thickness and balance in children with Duchene muscular dystrophy.

Materials and methods

Research design

This study was designed to be a prospective randomized controlled experimental study.

Participants

This research was carried out from January to April 2023. Thirty boys were chosen from Abu El-Rish Pediatric

Hospital in addition to the outpatient clinic at the Faculty of Physical Therapy. No children from either trial group discontinued therapy, as seen in Figure 1. The inclusion criteria: 1) Children diagnosed with DMD, 2) Aged between 6 and 10 years, 3) According to Kendall et al.[21], having lower extremities and trunk muscle strength of grade 3+, 4) Were able to move their upper and lower limbs normally, 5) Being able to walk unhindered at levels I and II of the Ambulation function classification system for DMD (AFCSD)[22]. The exclusion criteria: 1) Cardiopulmonary dysfunction or skeletal abnormalities that are either congenital or acquired; 2) Had previously experienced lower limb surgical procedure; 3) Had neurological conditions that affected their balance and gait or had poor motor development; 4) Exhibited behavioral disorders preventing them from cooperating during the trial; 5) Being overweight (body mass index (BMI) >25 kg/m^2) because a lot of fat makes it hard for the ultrasound to measure thickness[23]. This formula is BMI= kg/m^2, where kg is a child's body mass in kilograms and m2 is their height in meters squared[23].

Two groups of children each received a random assignment. after being selected from the clinic. Both groups (A and B) participated in physical treatment for three months; group A had traditional physical therapy in addition to TOE, whereas group B had the same physical therapy program with WBV three times per week for three consecutive months.

Randomization

The children were randomly assigned into two equal groups via the envelope mode. After patients agreed to participate in the study, cards with either "TOE" or "WBV" recorded on them were closed in envelopes; then a blinded physical therapist was asked to select one envelope. According to the selected card, children were assigned to their corresponding group. Dates for starting the allocated therapy were regulated and the therapy was begun after the first week of randomization.

Procedures

Assessment of abdominal muscle thickness

Four abdominal muscles' thicknesses were measured using ultrasonography (GE Logiq P6) at a frequency of 7.5 MHz. (the external oblique (EO), internal oblique (IO), rectus abdominus (RA), and transverse abdominus (TA). Using the umbilicus as a marker, the probe was moved in a semicircular motion until the sharpest image on the screen could be seen, and it was placed 2 to 3 centimeters from the midline. Using a skin marking pen, this position was verified and the thickness was measured. used a significant amount of contact gel and adjusted probe pressure to measure muscle thickness precisely. The thicknesses of four abdominal muscles were then measured using an oblique motion of the probe[24]. After capturing an image, a line was drawn vertically through the middle of the muscle, halfway between the superficial and deep aponeurosis. The researcher took three readings at various points along the muscle and averaged them.

Assessment of balance

All stability index variables (overall stability index, anteroposterior stability index, and mediolateral stability index) were evaluated utilizing the Biodex Balance System for balance evaluation. This equipment is manufactured by BIODEX MEDICAL SYSTEM, INC in the United States of America to test and train in both static and dynamic formats. Before the test, guidelines on how to complete the steps were given to all of the children. Each child was instructed to place both feet firmly on the center of the platform while maintaining a stable stance. The child was encouraged to stare directly at the biofeedback screen once the safety railings were readjusted. The child was then told to keep himself in the middle of the platform and to maintain an always erect posture. As the platform was being rotated, the child was instructed to keep their gaze fixed on the screen and keep the cursor in the middle. The test was conducted three times. After each trial was run, a report was written out detailing how the stability indices were measured.

Intervention procedures

Children in Groups A and B engaged in a regimented physical therapy treatment plan. It was utilized for three consecutive months for one hour, three times per week.

The following elements are part of this program: Warm up with gentle stretching movements to prevent injuries. The lower limb muscles on both sides were stretched for 20 seconds, followed by 20 seconds of relaxation, five times. The quadriceps, hamstrings, anterior tibial group, calf muscles, biceps, and triceps were also contracted isometrically. Every muscle contraction was held for 5 seconds, followed by 5 seconds of relaxation, and the process was repeated five times[25,26]. Gait and balance training with obstacles were also performed. Moreover, the following was provided:

Group (A): Both the TOE program and the traditional fitness program were given to fifteen children. Exercises with a focus on the trunk were designed with the patient's functional condition and active participation in mind. The patient underwent stretching exercises, active or active-assisted stabilization exercises, arm exercises with the trunk immobilized, trunk mobilization exercises (sitting and lying down), and functional reaching exercises with varying ranges of motion in shoulder elevation with the assistance of a physiotherapist[27,28].

Group (B): Fifteen children were put through the same regimen of physical therapy and WBV for a total of 10 minutes per session. The apparatus was set at 30 Hz frequency, 2 mm amplitude, and 5 minutes of operating time. The children were squatted down completely on a vibrating, side-alternating platform and were told to stay that way throughout the experience, communicating any pain they felt to the researchers. The vibration feature automatically shuts off after 5 minutes. After that, the children took a one-minute break. Then, with the same settings as those used in the squatting position, children stood on the vibration platform for 5 minutes. In each session, WBV was used for a total of 10 minutes[29].

Table 1. Participants' fundamental traits.

	TOE	WBV	*p*-value
	Mean ± SD	Mean ± SD	
Age (years)	6.22 ± 0.72	9.24 ± 0.71	0.81
Body mass (kg)	31.52±2.13	32.4±2.62	0.351
Height (cm)	123.18±3.1	124.62±2.18	0.218
BMI (kg/m^2)	20.83±0.75	21.07±0.23	0.321
Mean; SD, Standard deviation; p value, Probability value.			

Table 2. Mean abdominal muscle thickness pre and post intervention of the TOE and WBV groups,

	TOE	WBV	*p*-value
	Mean ± SD	Mean ± SD	
Abdominal muscle thickness (cm)			
EO **Pre treatment** **Post treatment**	0.320 ± 0.033 0.390 ± 0.028 ***p = 0.001***	0.288 ± 0.023 0.346 ± 0.032 ***p = 0.001***	0.52 0.001
IO **Pre treatment** **Post treatment**	0.422 ± 0.031 0.528 ± 0.041 ***p = 0.001***	0.418 ± 0.018 0.448 ± 0.024 ***p = 0.001***	0.26 0.001
TA **Pre treatment** **Post treatment**	0.328 ± 0.023 0.438 ± 0.027 ***p = 0.001***	0.318 ± 0.024 0.393 ± 0.028 ***p = 0.001***	0.17 0.001
RA **Pre treatment** **Post treatment**	0.524 ± 0.026 0.682 ± 0.039 ***p = 0.001***	0.518 ± 0.030 0.582± 0.040 ***p = 0.001***	0.14 0.001
SD, Standard deviation; p -value, Level of significance; EO, external oblique; IO, internal oblique; TA, transverse abdominus; RA, rectus abdominus.			

Table 3. Stability indices mean values in both groups before and after treatment.

		TOE	WBV	*p*-value
OSI	Pre	4.21 ± 0.71	4.32 ± 0.42	0.001
	Post	1.80 ± 0.61	2.22 ± 0.61	
***p*-value**		0.001	0.001	
APSI	Pre	3.12 ± 0.44	3.40 ± 0.21	0.001
	Post	1.21 ± 0.32	1.88 ± 0.36	
***p*-value**		0.001	0.001	
MLSI	Pre	2.21 ± 0.42	2.50 ± 0.61	0.001
	Post	1.01 ± 0.21	1.32 ± 0.36	
***p*-value**		0.001	0.001	
SD, Standard deviation; OSI, overall stability index; APSI, anteroposterior stability index; MLSI, mediolateral stability index; p-value, Level of significance.				

Statistical analysis

An unpaired t-test and descriptive statistics were used to compare the ages of the two groups. To make sure that the data followed a normal distribution, the Shapiro-Wilk test was utilized. We applied the test of Levene for homogeneity of variances to establish group consistency. The thickness of the abdominal muscle and balance were examined using a mixed-design MANOVA. Additional multiple comparisons were made using post-hoc testing with the Bonferroni correction. All statistical analyses were performed with a p-value of less than 0.05 considered significant. All statistical analysis was performed using SPSS version 25 for Windows (IBM SPSS, Chicago, Illinois, United States).

Results

Subject characteristics

As demonstrated in Table 1, there was no statistically significant difference in the two groups' ages, body mass, heights, and BMI ($p<0.05$). Height and body mass were measured using a KINLEF electronic personal scale with height measurement after removing shoes and their clothes were light.

Effect of treatment on abdominal muscle thickness

A significant interaction between treatment and time was discovered using mixed MANOVA. The main impact of time was statistically significant. The main treatment effect was statistically significant.

- Within-group comparison

After treatment, the abdominal muscle thickness in both groups increased significantly compared to pretreatment ($p>0.001$) (Table 2).

- Between-groups comparison

No statistically significant differences were found between pretreatment comparisons ($p>0.05$). Post-treatment comparisons showed that in the TOE group, EO, IO, TA, and RA abdominal muscle thickness increased significantly compared to the WBV group ($p>0.001$) (Table 2).

Effect of treatment on balance

- Within-group comparison

Multiple pairwise comparison tests (Post hoc testing) showed that all stability indices in both groups decreased statistically significantly ($p<0.05$) (Table 3).

- Between-groups comparison

When the two groups were compared after the completion of the program, group A was found to have a significant decrease in all stability indices compared to group B ($p<0.05$) (Table 3).

Discussion

The objective of the current study was to compare the effects of TOE and WBV on balance and the thickness of the abdominal muscles in children with DMD. The results of the current study reject the hypothesis that was supposed by the authors, as there was no difference between the effect of trunk-oriented exercises and whole-body vibration on abdominal muscle thickness and balance in children with Duchene muscular dystrophy. According to the author, this study is the first to look at how TOE and WBV affect abdominal muscle thickness and balance in these populations using specific inclusion criteria. However, little research has examined the impacts of TOE and WBV on children with DMD. The current findings demonstrated that both groups saw considerable improvements in balance and abdominal muscle thickness; however, the TOE group (A) made more advancements than the WBV group (B). The overall, anteroposterior, and mediolateral stability indices of the dynamic balancing test at pre-treatment mean values in the two groups showed no significant differences, although their values significantly increased. The enhanced trunk muscle strength brought on by the consistent physiotherapy program[30,31] may be the primary factor in both groups' improved balance. Balance and trunk muscular strength are directly related[32]. Through the length-tension relationship, trunk stabilization, which is enhanced by exercises, results in enhanced abdominal and spinal muscle strength, permitting even, deliberate movements[33]. All assessed variables in this study indicated improvement post-treatment, favoring the TOE group. Children with DMD experience balance disorders as a result of progressively weakening muscles[34]. Since balance disorders in these children restrict daily happenings, particularly gait, balance evaluation is crucial to detect treatment strategies[7]. According to the pretreatment findings, children with DMD frequently have balance disorders and weak abdominal muscles. These findings concur with those of Horlings et al.[34], who discovered that a persistent inflammatory response is what causes balance disorders and trunk instability brought on by gradual muscle weakness, a decline in muscular endurance, and aberrant muscle tissue repair. Both groups' post-treatment increases in balance and thicker abdominal muscles may be due to improvements in muscle strength and coordination on both body sides. A healthy neuromuscular system and enough muscle power are required, according to Karimi et al.[35], who stated that moving the center of mass inside the base of support when the balance is dispersed is considered a suitable motor response. Additionally, Petrof[36] and Lim et al[37]. stated that eccentric exercises or high-resisted exercises should be avoided in order to prevent the secondary functional deterioration of DMD, which was brought on by a lack of use and limited activities. This statement was supported by the significant results in both groups[36,37]. The findings of Bushby et al.[2], who concluded that current international standards advocate TOE for boys with DMD, supported the findings of the current study. Additionally, the findings that balance improvement occurred in both groups were consistent with Guskiewicz's[38] findings that various muscle groups, such as those in the neck, thigh, ankle, and trunk, are necessary to maintain a good postural balance. Our findings were further corroborated by the findings of Bogaerts et al.[39], whose research revealed that WBV training enhances strength and power, improving performance. The authors concluded that WBV enhances muscular mass via enhancing abdominal muscle strength. Furthermore, lean body mass and muscle strength are significantly associated, according to Cawthon et al.[40] WBV may therefore increase muscle mass as a result. The findings of this study, which are consistent with those of prior ones, show that children with Duchene muscular dystrophy can develop abdominal muscle strength[41]. The results of Aras et al.[7], who reported that strengthening the core muscles could enhance joint stability, co-contraction, and an improved capacity to shift weight in children with DMD, supported the improvement in balance that occurred in group A. Children in the TOE group in this study completed a specially adapted program for core stability since children with DMD need their core muscles to get into and out of standing postures. Guskiewicz[38] further said that the core muscles stabilize the middle of the body, enabling the upper and lower limbs to move in a regulated manner. Thus, the core stability program could be changed to help cerebral palsy children with balance and postural control. The improvement in favor of group A was reinforced by Güneş Gencer and Yilmaz[42] who concluded that trunk-oriented activities might improve trunk control and arm function in boys with DMD. This study is the first to look at how TOE and WBV affect abdominal muscle thickness and balance in DMD using specific inclusion criteria by using two recent methods to measure the improvement in abdominal muscle thickness and balance after applying two therapeutic modalities to evaluate their effectiveness in these children. Finally, TOE, according to our results, is significantly more effective than WBV at increasing the thickness of the abdominal muscles and balance in those children.

Study limitation

The current study has some limitations. The primary one was the lack of blinding of the physiotherapist who provided interventions, due to the type of intervention that needs direct communication between the physiotherapist and the patients. In addition, the small sample size limits the generalizability of the results. Furthermore, the study considered only the immediate effects of each type of exercise on the abdominal thickness and balance and did not reflect the long-term effects.

Conclusion

According to the current findings, the balance and abdominal thickness in children with DMD can both be significantly improved by TOE and WBV. Additionally, it has been found that TOE is significantly more effective than WBV at increasing the thickness of the abdominal muscles and balance in those kids.

Ethics approval

The study was approved by the ethics committee from the Faculty of Physical Therapy, Cairo University, Egypt (No: P.T.REC/012/004089).

Consent to participate

Written informed consent was obtained from the parents or legal guardians, which served as a reference for the processes and methods of treatment.

Authors' contributions

M.A. and M.S. contributed to the study concept and design, data analysis, and manuscript writing, including both the initial and final drafts. They were responsible for data collection and analysis. All authors contributed to the content and reviewed the manuscript for substance and similarity index. Additionally, they provided feedback and approved the final draft.

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