Original Research Article

Effects of Rebounding Exercises Versus Whole Body Vibration on Functional Capacity, Genu Recurvatum Angle and Bone Mineral Density in Children with Down Syndrome

Abstract

Aim: To compare the effects of rebounding exercises with whole body vibration on functional capacity, genu recurvatum angles and bone mineral density in children with Down syndrome.

Study design: Prospective, randomized controlled study

Place and Duration of Study: National Institute for Neuro-Motor System, Egypt, between June 2014 and September 2014

Methodology: Thirty children with Down syndrome (16 boys and 14 girls whose age ranged from 6 to 8 years). They were assigned randomly into two equal study groups. Study group I received rebounding exercise and study group II received whole body vibration. In addition, both groups received the same designed exercise program. Functional capacity via 6-minute walk test, genu recurvatum angles and bone mineral density were evaluated before and after 3 successive months of treatment.

Results: Significant differences were observed in both groups when comparing their pre and post-treatment mean values of all measuring variables ($p < 0.05$). Six minute walk test was changed from (300 ± 9.258, 294.667 ± 9.904) meters to (350 ± 8.451, 357.333 ± 13.741) meters for study group I and II respectively. Right genu recurvatum angles were changed from (20.330 ± 1.543, 19.730 ± 1.534) degrees to (17.800 ± 1.699, 16.130 ± 1.885) degrees for study groups I and II, respectively while left genu recurvatum angles were changed from (19.930 ± 1.486, 19.870 ± 1.407) to (17.600 ± 1.549, 15.067 ± 1.223) degrees for study groups I and II, respectively. Bone mineral density of femoral neck was changed from (0.576 ± 0.015, 0.580 ± 0.016) g/cm^2 to (0.805 ± 0.042, 0.831 ± 0.066); distal tibia changed from (0.335 ± 0.085, 0.339 ± 0.089) g/cm^2 to (0.485 ± 0.095, 0.549 ± 0.083) g/cm^2; proximal tibia from (0.557 ± 0.017, 0.565 ± 0.017) g/cm^2 to (0.781 ± 0.053, 0.827 ± 0.076) g/cm^2 for study groups I and II, respectively. Also, significant differences were recorded in genu recurvatum angles when comparing the post-treatment results of both groups in favor of the study group II ($p < 0.05$).

Conclusion: Both whole body vibration and rebounding exercises are effective in correcting genu recurvatum, low mineral density and decreased functional capacity for children with Down syndrome. But the whole body vibration is more effective than rebounding exercise regarding to correction of genu recurvatum angle.

Key words: Rebounding exercise, Whole body vibration, Bone mineral density, Functional capacity, Genu recurvatum, Down syndrome

1. Introduction

Down syndrome (DS) is caused by the triplication of human chromosome 21 resulting in genetic dosage imbalance thought to affect several different developmental pathways. It occurs in 1 in 700-800 live births **[1]**. The child may display a variety of symptoms which indicate decreased muscle tone. Motor skills delay is often observed along with hypermobile or hyperflexible joints, decreased strength, decreased activity tolerance, poor attention and motivation **[2]**.

Genu recurvatum of the knee is a position of the tibiofemoral joint in which the range of motion occurs beyond neutral or 0 degrees of extension **[3]**. Genu recurvatum defined operationally as knee hyperextension greater than 5 degrees. It is classified to: less than 15 degrees (physiological, asymptomatic, and symmetric), and more than 15 degrees (pathological, symptomatic, and asymmetric). Uncontrolled locking of the knee during standing and ambulation causes recurrent microtrauma which leads to degenerative changes and instability **[4]**.

Studies that evaluate bone density in DS are limited, and many are small case series in pediatric and adult populations who live either in the community or in residential institutions. Several environmental and hormonal factors contribute to low bone mineral density (BMD) in such patients. Muscle hypotonia, low amounts of physical activity (PA), poor calcium and vitamin D absorption, hypogonadism, growth retardation and thyroid dysfunction contribute to substantial impairments in skeletal maturation and bone-mass accrual **[5]**. Children with DS experience several barriers to participate in daily PA like transportation restrictions, low motivation and lack of integrated program options **[6]**. Consequently, low levels of PA **[7]** and physical fitness **[8]** have been described in this population. Physical activity has an important role in bone mass acquisition due to its osteogenic effects **[9]**. Therefore, DS population might be considered as a population at higher risk of suffering bone fractures and osteoporosis **[10]**.

Functional ability was determined by means of six minute walk test (6MWT) **[11]**. This test can present an indirect assessment of someone's capacity during activities of daily living, and it can be used to follow-up evolution during treatment **[12]** and to measure walking ability and baseline cardiovascular function of people with disease or low levels of fitness **[13]**. More recently, the test has been validated in several populations, including patients with fibromyalgia, cerebrovascular accident, amputations, morbid obesity, DS, Alzheimer's disease and cerebral palsy **[14]**. In healthy children, the 6-min walk test is a reliable and valid functional test for assessing exercise tolerance and endurance **[15]**.

In rehabilitation programs, it is a challenge to find a way to stimulate the sensorimotor system toward regaining normal voluntary movement and limb functional use. The goal of most therapy programs is to maintain the affected extremity in the best possible aligned position to avoid overstretched soft tissue, edema, and pain. Through the exercise program and use of weight-bearing techniques, the therapist attempts to maintain and improve trunk and limb alignment to allow the functional use of the extremity **[16]**. Conservative rehabilitation of genu recurvatum should be focused on more complex activities and sports- specific skills **[17]**.

Techniques that involve proprioceptive, vestibular, and visual inputs are so beneficial to children with DS **[18]**. The use of rebound therapy with children with both physical and learning disabilities is expanding **[19]**. Rebound therapy should be used as part of a therapy program adding to existing therapies and not in isolation the treatment program **[20]**. Rebounding from quality mini trampolines provides all the benefits of other aerobic exercise without the stress impact usually associated with vigorous activity. When exercising on the floor or jogging as vertical shock waves spread from the ankles, through bones and spine, and minor nerve damage may well occur at the root of the pelvis. Joggers often end up with micro-trauma injuries to heels and ankles **[21]**. A method for muscle strengthening that is increasingly used in a variety of clinical situations is whole-body vibration (WBV) **[22, 23]**. It is practiced while the user is standing in a static position or moving in dynamic movements **[24]**. Some studies have also found that WBV can increase BMD **[25, 26, 27]**.

Therefore, the purpose of this study was conducted to compare between the effects of rebounding exercise and WBV on functional capacity, genu recurvatum angles and BMD in children with DS.

2. Subjects, Randomization and Methods

2.1. Subjects

Thirty children with DS from both sexes were enrolled in this study via National Institute for Neuro-Motor System, Egypt. Their ages ranged from 6 to 8 years. They were able to understand the commands given to them. They were able to stand and walk independently. They had bilateral genu recurvatum angles ranged from 15 to 30 degrees as determined by plain x-ray measurement. The strength of quadriceps, hamstring and calf muscles is at least grade 3 according to Kendall et al. **[28]**.

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The exclusion criteria included the following: children with medical conditions that would severely limit their participation in the study such as vision or hearing loss, cardiac anomalies, pulmonary disorders, thyroid abnormality, atlanto-axial instability or other musculoskeletal disorders. Children who had a history of previous surgical operation, or took any medicines that affected bone density were excluded from the study. The children, who were not familiar with the program of the study, took them after the familiarly session were excluded from the study.

This work was carried out in accordance with the code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Parents of the children signed a consent form prior to participation as well as acceptance of the Ethical Committee of Cairo University was taken. All the procedures involved for evaluation and treatment, purpose of the study, potential risks and benefits were explained to all parents.

The children were classified randomly into two groups of equal number: study group I including 15 children (7 boys, 8 girls) received rebounding exercise and study group II including 15 children (8 boys, 7 girls) received WBV. In addition, both groups received the same designed exercise program.

2.2. Randomization

Forty three children were assessed for eligibility. Ten children were excluded as they did not meet the inclusion criteria and three children were excluded as their parents refused to participate in the study. Following the baseline measurements, randomization process was performed using closed envelopes. The investigators prepared 30 closed envelopes with each envelope containing a card labeled with either study group I or study group II. Finally, each child was asked to draw a closed envelope that contained whether he/she was allocated to the study group I or II. The study design is demonstrated as a flow chart in Figure 1.

2.3. Methods

2.3.1. For evaluation

Preliminary evaluation:

Several demographic, anthropometric and physiological factors can influence the 6MWT in healthy individuals and in patients with chronic diseases. Shorter individuals and women present a shorter step length and consequently, a shorter 6MWT. Obese individuals commonly present reduced lean body mass and, consequently, a shorter 6MWT **[12, 29]**. So, the weight and height were recorded using electronic weighing and measuring station. Neck x-ray was taken to exclude atlanto-axial instability.

Preliminary tests which were familiarly sessions for WBV, rebounding, 6MWT and the designed physical therapy program were done for exclusion criteria. The children who were not familiar were excluded from the sample before randomization.

Functional capacity, genu recurvatum angles and BMD were evaluated by using 6MWT, plain X-ray of bilateral knee joints, Dual Energy X-ray Absorptiometry (DEXA) respectively***.*** The evaluation was done before and after 3 successive months of treatment.

2.3.1.1. Six Minute Walk Test

Six minute walk test is a sub-maximal test of aerobic capacity, in which the subjects walk as far as possible in 6 minutes (min.) around a pre-measured distance. It is a useful assessment tool for children with chronic conditions affecting the musculoskeletal system, because walking is a part of their everyday life **[30]**. Children were allowed to walk on an unobstructed, rectangular pathway following the guidelines of the American Thoracic Society. The therapist followed closely the children while walking to ensure safety and to measure the exact walked distance by using a stopwatch. The walking course distance of 20 meters (m) between turning points was used. Each child was instructed to cover as many laps of the course as possible in 6 min. without running **[31]**. A familiarity session occurred prior to the test session. On this session, the children practiced 6MWT. This session was particularly necessary for the children to ensure their comfort with the research team and protocol of evaluation.

2.3.1.2. Plain X-ray

Unilateral standing (weight bearing) X-ray film was taken. FUJIFILM Corporation Model, CR.IR 357 Fuji-computed RADIOGRAPHY, apparatus was used. The child stood holding on rail, mother's hands, or assistant's hands. Then, the child was asked to flex one leg (untested leg) "unilaterally weight bearing". The film was taken from 90 degrees with a distance 90 cm from the child's knee. The same procedure was applied to the other knee. The tibiofemoral angle was measured. This angle results from intersection of two lines, the first is the anatomical axis of the femur, and the second is the anatomical axis of the tibia. The anatomical axis is the line that lies longitudinally in the middle of the shaft of the long bones **[32]**.

2.3.1.3. Dual Energy X-ray Absorptiometry

Dual energy X-ray absorptiometry (Prodigy GE Lunar, enCORE software) was used for the evaluation of BMD and monitoring of the effects of treatment on bone sites. It is most commonly used in children and adults. It is an efficient, precise and safe method that has a relatively low cost and widespread availability **[33]**. It consists of a central device with a padded platform and a mechanical arm (scanner) that is adjusted to emit low dose x-ray on the area required to be measured. The equipment is combined with a computer device with specific software to determine BMD. The DEXA was used for measuring BMD of the femoral neck, proximal tibia and distal tibia with a very low dose of radiation and acceptable precision using bone mineral content in grams (g) by area of bone measured (cm^2) expressing density as g/cm^2.

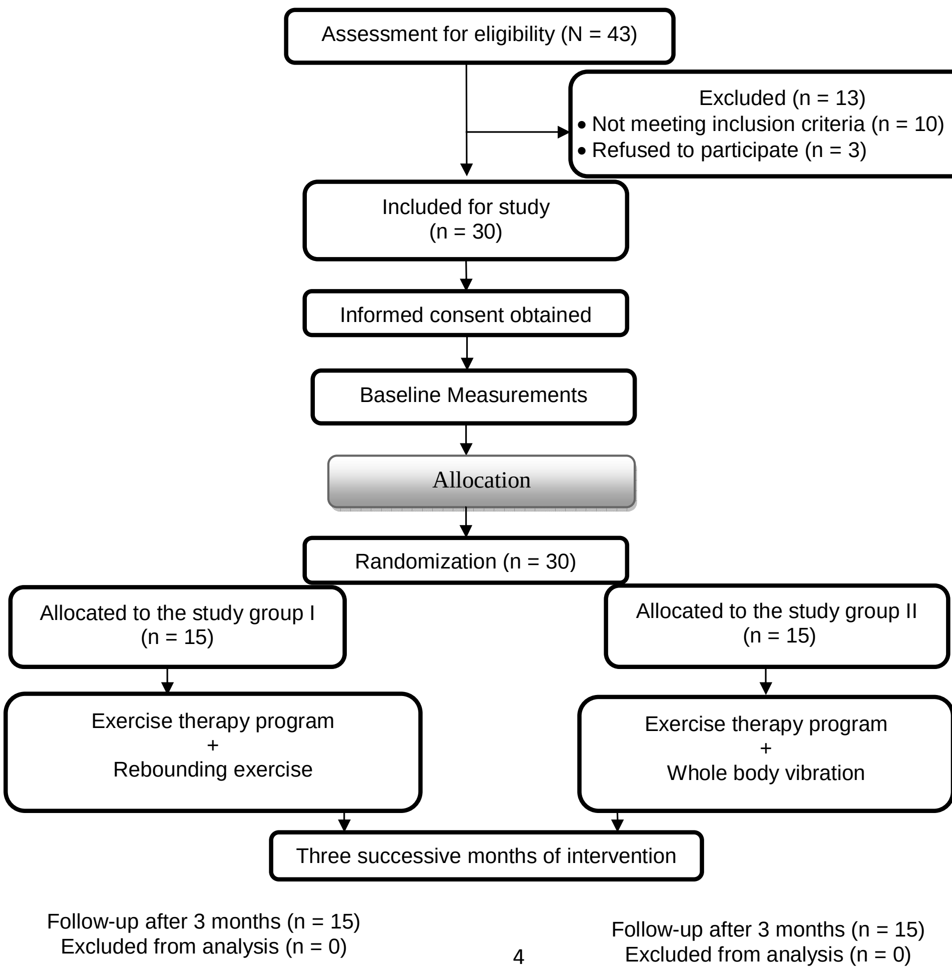

Figure 1: Flow chart ~~showing the experimental design~~ of the study design

2.3.2. For treatment

2.3.2.1. Rebounding exercise

The children in group I received rebounding exercise 3 times per week for 3 successive months. Mini trampoline: 1.02 m in diameter and about 0.03 m high for a model with 6 legs, also have 1.02 m inches long bar at the trampoline side fixed with the trampoline by 3 longitudinal bars with 0.61 m in height that gave the child something to hold onto if child was at risk for falling due to disturbance of the balance.

The duration of treatment session was based on our pilot work and the work of others who recommended it for 15 min or more a day, though this can be broken in to multiple 3-5 min groups **[34]**. Each rebounding session consisted of the following schedule: (3 min of rebounding) – (3 min rest) – (3 min of rebounding) – (3 min rest) – (3 min of rebounding). Thus, one treatment session corresponded to 9 min. of rebounding exercise.

The bouncing started slowly as a warming up in short blocks for 5 min. as conducted by Witham et al. **[35]** in their study who mentioned that, the sessions included: a long warm up taking the child through sitting transitions (long sitting, side sitting and high kneeling); bouncing and/or being bounced without leaving the surface of the trampoline. Then, the child stood at the trampoline with his/her feet at the shoulder width and the therapist stood behind the child bouncing with him and guided the bounce. The child began to bounce up and down with maintaining a steady balance by holding on the hand bar. As the child could bounce alone, the therapist just controlled the bounce by asking the child to fast or slow the bounce (hand free manner) **[19]**. The therapist could control the bouncing by holding the child's legs or feet to increase the bouncing rate. This gradually increased the bounce rate as the endurance increased.

2.3.2.2. Whole body vibration

The children in group II received WBV 3 times per week for 3 successive months. A commercially available WBV device (Vibraflex Home Edition II®, Orthometrix Inc, White Plains, NY) was used. It has a motorized board that produces side-to-side alternating vertical sinusoidal vibrations around a fulcrum in the mid-section of the plate. The frequency of the vibrations could be selected by the user. The peak-to-peak displacement, to which the feet were exposed, could be increased with increasing the distance of the feet from the center line of the vibrating board.

Three positions were indicated on the vibrating board, marked as '1', '2' and '3', which corresponded to peak to-peak displacements of 2 mm, 4 mm and 6 mm. The treatment schedule was adapted from published observational studies that had used the same WBV system as the present study to treat children with neuromuscular diseases and bone fragility disorders **[~~37~~36, 37]**.

Each WBV session consisted of the following schedule: (3 min of WBV) – (3 min rest) – (3 min of WBV) – (3 min rest) – (3 min of WBV) of WBV. Thus, one treatment session corresponded to 9 min. of exposure to WBV. The vibration settings used for each treatment session were documented as well as other clinical observations made during the vibration sessions. The session was terminated if the child complained of fatigue or pain. The child stood on the board with both feet touching the vibration plate. The feet were placed at an equal distance from the center of the board. The children wore shoes during the WBV sessions to have a more stable position on the vibration plate. The child was initially attached to the tilt table with two straps, one at the level of the pelvis and the other on the level of the knees. The initial tilt angle was set to 35 degrees.

The goal for the subsequent sessions was to increase the angle of the tilt table and to eventually perform the WBV without a tilt table, using a WBV device placed on the ground. The speed of the progress toward this goal depended on the child's ability to maintain an upright posture under the conditions of WBV. The first treatment sessions were performed using a vibration frequency of 12 Hz, with the middle toe of each foot placed 5.5 cm from the neutral axis of the vibration plate (indicated as position '1' on the WBV device). The peak acceleration exerted by vibration increased with the frequency and the amplitude of the vibration. Therefore, higher frequency and higher amplitude were likely to elicit higher musculoskeletal force. The goal was to increase the vibration frequency to 18 Hz (in steps of 0.5 Hz every two treatment sessions) and the peak-to-peak displacement to 4 mm (as determined for the middle toe of each foot). The frequency was increased only if the child felt comfortable with the setting. Once the frequency of 18 Hz was reached, the feet were gradually placed wider apart until they were vertically below the hip joint. These target settings corresponded to a peak acceleration of approximately 2.6 g and were based on our previous experience from a small observational study which indicated that these settings are usually well tolerated by children with DS **[38]**. Thus, the middle toe of each foot was eventually placed between 8 cm and 11 cm from the neutral axis of the vibration plate, depending on the width of the child's pelvis. Whether using the tilt table or the ground-based WBV system, the children flexed their knees and hips between 10 and 45 degrees (to prevent the vibration from extending up to the head). Guided by the study physiotherapist, the children shifted their weight from side to side or increased and decreased the knee and hip angle. Other exercises included weight shift with rotation of the trunk, and alternate flexion and extension of knees. Postural correction was encouraged through visual feedback (by performing the treatment in front of a mirror) and through the therapist's verbal cueing.

In addition, the children in both groups received the same designed exercises program. The total program lasted for 1 hour, 3 times/ week for 3 successive months. The program included the following items with clear instructions to the child to perform:

1. Standing with feet together while the therapist was sitting behind and manually locking the child knees, and then slowly tilting him to each side, forward and backward for 5 min.
2. Step standing with the therapist behind the child guiding him to shift his weight forward then backward alternately for 5 min.
3. High step standing and trying to keep balanced. The child stood on exercise mattress. The child was asked to lift his/her leg and put it at a step (small blocks) and maintain for 5 min for each leg alternately while the therapist sat behind.
4. Single leg stance "unilateral standing" with assistance. The child was standing on exercise mattress. The therapist sat behind and elevated the child's leg and asked the child to maintain standing balanced on the other leg for 5 min for each leg alternately.
5. Standing on a declined surface" by using wedge". The child was standing on wedge towards the descending direction. The therapist asked the child to maintain balanced standing in declined direction for 5 min.
6. Standing with manual locking of the knees then trying actively to stoop and recover for 5 min.
7. Changing position from squatting to standing and from kneeling to standing(5 min for each position)
8. Open environment gait training: Forward, backward, and sideways walking obstacles including rolls and wedges with different diameters and heights for 10 min.

Statistical analysis

The collected data of the functional capacity, genu recurvatum angles and BMD of both groups were statistically analyzed to compare the effects of rebounding exercise with whole body vibration. Descriptive statistics were done in the form of mean and standard deviation (SD) to all measuring variables in addition to the age, weight and height. Paired t-test was conducted for comparing pre and post-treatment mean values in each group. Unpaired t-test was conducted to compare pre and post treatment mean values of all measuring variables between both groups. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through SPSS (Statistical Package for Social Sciences, version 20). The percentage of improvement was calculated according to:

$$\text{Percentage of improvement} = \frac{\textbf{post} - \textbf{pre}}{\textbf{pre}} \times 100$$

3. Results

3.1. Subjects' characteristics

The mean and standard deviation of the age were (7.11±0.56, 7.52 ±0.63 years) for groups I, II respectively. There were no significant differences between both groups pre-treatment in the mean age, P =0.070. The mean and standard deviation of anthropometric data including weight, height and body mass index (BMI) are presented in table 1. There were no significant differences between both groups in the pre-treatment mean values of anthropometric data, P =0.599, 0.308, 0.596 for weight, height and BMI respectively. No significant differences were recorded in the mean values of anthropometric data of both groups when comparing their pre and post-treatment mean values (*P* < 0.05) as presented in table 1. There were no significant differences between both groups in the post-treatment mean values, *P* = 0.661, 0.305, 0.607 for weight, height and BMI respectively.

TTable 1. Anthropometric data of both groups

	Group I (n=15)			Group II (n=15)		
	Weight (kg)	Height (cm)	BMI (kg/m^2)	Weight (kg)	Height (cm)	BMI (kg/m^2)
Pre	27.06± 3.79	115.12± 4.59	21.32± 1.83	27.86±4.43	117.33±6.85	20.92±2.23
Post	27.26± 3.87	115.16± 4.60	21.33± 1.84	27.93±4.39	117.37±6.78	20.94±2.25
t-test	0.143	0.024	0.015	~~0996~~0.996	0.016	0.025
p-value	0.887	0.981	0.998	0.044	0.987	0.981

3.2. Six- minute walk test

The raw data of the 6MWT for both groups were statistically treated to determine the mean and standard deviation presented in table 2. Student-test was then applied to examine the significance of the treatment conducted for each group. The obtained results revealed no significant differences when comparing the pre-treatment mean values of both groups (*P* = 0.139). Significant differences were observed in both groups, when comparing their pre and post-treatment mean values (*P* < 0.05) as presented in table 2. Meanwhile, no significant differences were recorded when comparing the post-treatment mean values of both groups (*P*= 0.089).

Table 2. Six minute walk test for both groups

	Group I (m)	Group II (m)
Pre	300.00 ± 9.258	294.667 ± 9.904
Post	350.00 ± 8.451	357.333 ± 13.741
% of improvement	16.67%	21.26%
t-test	-36.228	-15.706
p-value	0.001*	0.001*

* Significant at *P* < 0.05

3.3. Genu recurvatum angles

The mean and standard deviations of right and left genu recurvatum angles are presented in table 3. There were no significant differences between both groups when comparing their pre-treatment mean values *P* = 0.295, 0.910 for right and left genu recurvatum angles respectively. Significant differences were recorded in both groups, when comparing their pre and post-treatment mean values (*P* < 0.05) as presented in table 3. Significant differences were recorded when comparing the post-treatment mean values of both groups *P* = 0.017, 0.0001 for right and left genu recurvatum angles respectively, in favor of the group II.

Table 3. Genu recurvatum angles for both groups

	Group I (n=15)		Group II (n=15)	
	Rt. Knee (degrees)	Lt. knee (degrees)	Rt. Knee (degrees)	Lt. knee (degrees)
Pre	20.330 ± 1.543	19.930 ± 1.486	19.730 ± 1.534	19.870 ± 1.407
Post	17.800 ± 1.699	17.600 ± 1.549	16.130 ± 1.885	15.067 ± 1.223
% of improvement	-12.5	-11.7	-18.3	-24.2
t-test	5.824	18.520	15.317	11.860

p-value	0.0002*	0.0002*	0.0001*	0.0001*

* Significant at $P < 0.05$ Rt.: right Lt: left

3.4. Bone mineral density

The mean and standard deviation of both groups are presented in table 4. There were no significant differences when comparing the pre-treatment mean values of both groups, P = 0.486, 0.901, 0.211 for femoral neck, distal tibia and proximal tibia respectively. Significant differences were recorded when comparing their pre and post-treatment mean values ($P < 0.05$) as presented in table 4. Also, no significant differences were observed when comparing the post-treatment results of both groups, P = 0.209, 0.059, 0.065 for femoral neck, distal tibia and proximal tibia respectively.

Table 4. Bone mineral density measured for both groups

	Group I (n=15)			Group II (n=15)		
	Femoral neck (g/cm^2)	Distal tibia (g/cm^2)	Proximal tibia (g/cm^2)	Femoral neck (g/cm^2)	Distal tibia (g/cm^2)	Proximal tibia (g/cm^2)
Pre	0.576 ± 0.015	0.335 ± 0.085	0.557 ± 0.019	0.580 ± 0.016	0.339 ± 0.089	0.565 ± 0.015
Post	0.805 ± 0.042	0.485 ± 0.095	0.781 ± 0.053	0.831 ± 0.066	0.549 ± 0.083	0.827 ± 0.076
% of improvement	39.90	44.20	40.30	58.10	63.88	46.2
t-test	-18.646	-4.165	-14.312	-19.363	-6.633	-13.459
p-value	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*

* Significant at $P < 0.05$

5. Discussion

Genu recurvatum is a consequence of poor control over the knee joint due to muscle weakness, impaired tonus, and deficit in joint proprioception **[39]**. Decreased step length, stride length, velocity, and cadence are primary functional gait deviations associated with this deformity. Increased lateral trunk displacement and increased energy costs also are likely to be noted **[40]**. The present study was essentially planned aiming to compare between the effects of rebounding exercise and whole body vibration on functional capacity, genu recurvatum angle and BMD in children with DS.

Comparing between the mean values of pre-treatment results of 6 MWT, genu recurvatum angles and BMD revealed no significant differences between both groups. This comparison showed bilateral pathological genu recurvatum, decreasing of 6 MWT and BMD in comparison to the normal values of the children in the same age group **[4, 41, 10]**. These results were explained by Martin et al. **[2]** who stated several musculoskeletal and neuromuscular system impairments found in children with central hypotonia. These impairments included motor skills delay, hypermobile or hyperflexible joints, decreased strength, decreased activity tolerance, poor attention and motivation, and poor reflexes. Peredo and Hannibal **[42]** added that, the complex feedback loops of sensory processing and motor output were implicated. There were often sensory processing deficits (vestibular, proprioceptive, visual, and tactile) that were not alerting the brain of changes in body position.

After the suggested period of treatment, significant improvement in the mean values of all measuring variables was recorded in both groups. This improvement could be attributed to the combined effect of a designed exercise program and sensory stimulation through rebounding exercise or WBV. Rebounding exercise or WBV ~~worke~~work at a multi-system level, the visual, proprioceptive, and vestibular inputs leading to modulation of muscle tone which encouraged the appearance of normal motor response, enhanced the relationship between the sensory and motor system, and improved the sensorimotor integrative process. This was confirmed by Root **[43]** who stated that, normalization of muscle tone and evocation of desired muscular response accomplished through usage of appropriate sensory stimuli. Rine **[44]** reported that, stimulation of otolithic organs by transient linear acceleration and/or by changes in head position with respect to gravity evoked phasic and tonic vestibule–ocular and vestibule–spinal reflexes, which acted on the head and limbs to maintain posture. Smith and Cook **[45]** added that, the rebounding had been observed to decrease hypotonia with the correct application, as vigorous bouncing increases tone by stimulating the sensory systems.

The functional weight-bearing exercise programs provide an improved and more consistent proprioceptive feedback that in turns improves the control of movement. These exercises have been shown to have an improving effect on balance, gait, and lower-limb strength among children with DS with moderate or no cognitive impairments **[46]**. In addition, the weight-bearing exercises allow for reactivation of the proprioceptors **[47]**. Proprioceptive input to central nervous system is very important for conscious awareness of joint position sense and motion so clinicians need to evaluate kinesthetic deficits and to design exercise programs to improve kinesthetic awareness **[4]**. Exercise has an important osteogenic effect, mainly when high-impact and weight bearing PA occur. At the same time, the mechanostat theory suggests that both systematic exercise and PA could drive to a direct osteogenic effect on bone mass and an indirect osteogenic effect by increasing muscle size and strength and hence the tensions generated on bones **[48]**.

Comparing the pre and post-treatment results of the 6_MWT of both groups, it was observed that functional ability level of the children was improved. These results were consistent with the findings of the American Thoracic Society which emphasized that several factors may be contributed to functional improvement as increased stride length because of improving muscular endurance, cardiopulmonary efficiency, circulation and biomechanical loading on the joints resulting in a more comfortable and efficient gait. Behavioral and psychological factors such as increased confidence, improved body image, and decreased fear of movement or injury could also result in improvement in functional walking **[31]**.

The control centers in the brain use the signals to develop a subjective awareness of the knee position in relation to the environment and relate these experiences to those of other sensory systems during standing. The connection with reticular formation induces increased alertness and awareness. So these interactions of various systems lead to orientation of the child in space. This comes in agreement with the study of Walker **[49]** who reported that, rebounding stimulate neural activity, engage every brain and body cell. Disabled children exhibiting a poor sense of rhythm, coordination, and balance have been shown to benefit through improving the mind/body connection.

Rebound exercise can combine two important aspects: strengthening and aerobic oxygen **[50]**. It's exhilarating to jump up and experience weightlessness for a split second and then come down with an extra gravitational force **[51]**. Jumping activity effectively evoked the automatic and dynamic postural control. Moreover, the standing performances might be improved due to the transferred effects via the practice of dynamic jumping activity as reported by Wang and Chang **[52]**. Adding to that, the willing of the child to participate in the rebounding exercise with great happiness and confidence, which considered as an attractable and enjoyable playing therapy **[53]**.

Low amplitude, low frequency mechanical stimulation of the human body is a safe and effective way to exercise musculoskeletal structures. In fact, increases in muscular strength and power in humans exercising with specially designed exercise equipment have been reported **[54, 55, 56]**. Whole body vibration has been recently proposed as an exercise intervention because of its potential for increasing force generating capacity in the lower limbs. Its recent popularity is due to the combined effects on the neuromuscular and neuroendocrine systems. Preliminary results seem to recommend vibration exercise as a therapeutic approach for sarcopenia and possibly osteoporosis **[57]**. Torvinen et al. **[58]** showed a net improvement of 8.5% in vertical jumping ability after four months of WBV performed with static and dynamic squatting exercises with small vibration amplitudes (2 mm) and frequencies ranging from 25 to 40 Hz in sedentary subjects.

Three studies focused on children and adolescents with low BMD **[59]**. One study included male and female children with osteogenesis imperfecta, a disease characterized by brittle bones **[37]**. One study included female children with endocrine disorders that had low BMD and were not taking any medication that could affect their bones **[60]**. The third study included white female adolescents with low BMD who had previously sustained a fracture. Participants in this study had no underlying diseases or chronic illnesses, were not taking any medications, and had completed puberty **[61]**.

Unger et al. [62] recommended in their study the use of vibration in the rehabilitation program of children with spastic diplegia aiming to improve the posture and gait.

A recent study conducted by Eid **[63]** concluded that WBV may be a useful intervention modality to improve balance and muscle strength in children with DS.

No significant differences were recorded between both groups regarding to BMD and 6 MWT when comparing the post treatment results of both groups. In the same time, significant differences were recorded in genu recurvatum angles in favor of the study group II. This is supported by Delecluse et al. **[64]** and Roelants et al. **[55]** who highlighted the possibility of long term programs of WBV that may produce significant improvements in muscle function of the leg extensors in untrained subjects.

As more supportive evidence, a recent study showed that WBV therapy was superior to a low intensity resistance training programs in improving isometric and dynamic muscle strength in middle aged and older women **[55]**.

A mini-trampoline is similar to the effects of WBV but the WBV works at a much faster speed **[65]**. All the muscles in the body are activated and exercised at the same time with WBV. A rebounder produces these muscle contractions every bounce, but the low-impact, oscillating platform of a WBV produces the same reaction up to 30 times per second **[66]**.

Our study has had some limitations. Some children with DS had atlanto-axial instability. So, neck x-rays were done prior to the study. Preliminary tests which were familiarly sessions for WBV, rebounding, 6 MWT and the designed physical therapy program were done for exclusion criteria. The children who were not familiar with that were excluded from the sample before randomization. Trying to avoid the factors which could affect BMD during the study, we excluded children with hypothyroidism or those taking medication affecting BMD. There was no calcium or vitamin D intake throughout the study. We followed the growth of the children throughout the study which could affect BMD and 6 WMT, comparing pre and post-treatments. Trying to overcome the lack of sensitivity of 6 MWT, we excluded children with medical conditions that would severely limit their participation in the study such as vision or hearing loss, cardiac anomalies, pulmonary disorders and a familiarity session was done prior to the test session. We tried to minimize interpretation bias by evaluating our data with the members of the research group and discuss our results constantly during the entire analysis process. The transcript translation into English may have resulted in native English speaker with a medical background. Our sample is not big enough and our findings related to Egyptian children. So, further researches are needed to be conducted on a larger group of children in different countries.

6. Conclusion

From the obtained results of the current study, it can be concluded that the rebounding exercise and whole body vibration are effective additional tools to the rehabilitation program with genu recurvatum, low mineral density and decreased functional capacity for children with Down syndrome. But the whole body vibration has significant effect in relation to rebounding exercises regarding to correction of genu recurvatum angle.

References

1. Schieve LA, Boulet SL, Boyle C, ~~Rasmussen SA~~Rasmussen SA, Schendel D. Health of children 3 to 17 years of age with Down syndrome in the 1997-2005 national health interview survey. Pediatrics 2009; 123 (2):e253–60. doi: 10.1542/peds.2008-1440. [PubMed]
2. Martin K, Inman J, Kirschner A, Deming K, Gumbel R, Voelker L. Characteristics of hypotonia in children: a consensus opinion of pediatric occupational and physical therapists. Pediatr Phys Ther. 2005; 17(4):275-82. [PMID:16357683]
3. Lario S, Brandon ML, Bonamo JR, Flynn MI, Sherman MF. Genu recurvatum presenting as PCL insufficiency. J Knee Surg. 2004; 17(4): 214-217. doi: 10.1055/s-0030-1248224
4. Loudon Jk, Goist HL, Loudon KL. Genu recurvatum syndrome. JOSPT 1998; 27(5): 361-67.
5. Hawli Y, Nasrallah M, El-Hajj Fuleihan G. Endocrine and musculoskeletal abnormalities in patients with Down syndrome. Nat Rev Endocrinol.2009; 5(6): 327–334. doi: 10.1038/nrendo.2009.80. [PubMed]
6. Sayers Menear K. Parents' perceptions of health and physical activity needs of children with Down syndrome. Down Syndr Res Pract. 2007; 12(1):60–68. [PMID:17692190]

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7. Esposito PE, Macdonald M, Hornyak JE, Ulrich DA. Physical activity patterns of youth with Down syndrome. Intellect Dev Disabil. 2012, 50(2):109–119. doi: 10.1352/1934-9556-50.2.109. [PubMed]
8. Fernhall B, Pitetti KH. Limitations to physical work capacity in individuals with mental retardation. Clin Exer Physiol. 2001; 3:176–185.
9. Gracia-Marco L, Moreno LA, Ortega FB, Leon F, Sioen I, Kafatos A, Martinez- Gomez D, et al. Levels of physical activity that predict optimal bone mass in adolescents: the HELENA study. Am J Prev Med. 2011; 40(6):599–607. doi: 10.1016/j.amepre.2011.03.001.
10. Matute-Llorente A, González-Agüero A, Gómez-Cabello A, Vicente-Rodríguez G, Casajús JA. Decreased levels of physical activity in adolescents with Down syndrome are related with low bone mineral density: a cross-sectional study. BMC Endocrine Disorders 2013, 13:22. doi:10.1186/1472-6823-13-22.
11. Burr JF, Bredin SS, Faktor MD, Warburton DE. The 6-minute walk test as a predictor of objectively measured aerobic fitness in healthy working-aged adults. Phys Sportsmed. 2011; 39(2):133–9. doi: 10.3810/psm.2011.05.1904. [PubMed]
12. Enright PL. The six-minute walk test. Respir Care. 2003; 48(8):783-5. [PMID:12890299]
13. Whaley MH, Brubaker PH, Otto RM, Armstrong LE. ACSM's guidelines for exercise testing and prescription. 7th ed. Philadelphia, Penns. ; London: Lippincott Williams & Wilkins, 2006.
14. Vis JC, Thoonsen H, Duffels MG, de Bruin-Bon RA, Huisman SA, Van Dijk AP, **et al.** Six-minute walk test in patients with Down syndrome: validity and reproducibility. Arch Phys Med Rehabil. 2009; 90 (8): 1423-7. doi: 10.1016/j.apmr.2009.02.015. [PubMed]
15. Li AM, Yin J, Yu CC, Tsang T, So HK, Wong E, et al. The six-minute walk test in healthy children: reliability and validity. Eur Respir J. 2005; 25(6):1057-60. [PMID: 15929962]
16. Jaraczewska E, Long C. Kinesio taping in stroke: improving functional use of the upper extremity in hemiplegia. Top Stroke Rehabil. 2006, 13 (3): 31–42. [PMID: 16987790]
17. Herring JA. Tachdjian's pediatric orthopaedics. 3rd ed. Philadelphia: W.B. Saunders Company, 2002: 825-829.
18. Connolly BH, Morgan SB, Russely FF, Fulliton WL. A longitudinal study of children with Down`s syndrome who experienced early intervention programming. Phys Ther. 2010; (73): 171-81.
19. Roberts D. Bounce benefits. Physiotherapy Frontline 2006; 12 (3): 12-14.
20. Smith S, Cook D. A study into the use of rebound therapy for adults with special needs. Phys Ther. 1990; 76 (11): 734-735.
21. Carter AE. Rebound exercise: The ultimate exercise for the new millennium. National Better World Books (Mishawaka, IN, U.S.A.) 2006.
22. Prisby RD, Lafage-Proust MH, Malaval L, Belli A, Vico L. Effects of whole body vibration on the skeleton and other organ systems in man and animal models: what we know and what we need to know. Ageing Res Rev 2008; 7:319–29.
23. Rittweger J. Vibration as an exercise modality: how it may work, and what its potential might be. Eur J Appl Physiol 2010, 108:877–904.
24. Woollacott MH, Shumway-Cook A. Postural dysfunction during standing and walking in children with CP: What are the underlying problems and what new therapies might improve balance?. Neural Plast. 2005; 12 (2-3): 221-9.
25. De Zepetnek JO, Giangregorio LM, Craven BC. Whole body vibration as potential intervention for people with low bone mineral density and osteoporosis: a review. J Rehabil Res Dev 2009; 46:529–42.
26. Park H, Kim KJ, Komatsu T, Park SK, Mutoh Y. Effect of combined exercise training on bone, body balance, and gait ability: a randomized controlled study in community-dwelling elderly women. J Bone Miner Metab. 2008; 26(3):254–259.
27. Rizzoli R, Bianchi ML, Garabédian M, McKay HA, Moreno LA. Maximizing bone mineral mass gain during growth for the prevention of fractures in the adolescents and the elderly. Bone. 2010; 46(2):294–305.
28. Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. Muscles: testing and function with posture and pain. 5th ed., Lippincott: Williams and Wilkins, 2005: 49.
29. Enright PL, McBurnie MA, Bittner V, Tracy RP, McNamara R, Arnold A, et al. The 6-min walk test: a quick measure of functional status in elderly adults. Chest. 2003; 123 (2): 387-98.

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30. Hassan J, vander Net J, Helders PJ, Prakken BJ, Takken T. Six-minute walk test in children with chronic conditions. Br J Sports Med. 2010; 44(4):270–4.
31. American Thoracic Society. Guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002; 166:111–7. Available: https://www.thoracic.org/statements/resources/pfet/sixminute
32. Ariumi A, SatoT, Kobayashi K, Koga Y, Omori G, Minato I, et al. Three-dimensional lower extremity alignment in the weight-bearing standing position in healthy elderly subjects. J Orthop Sci. 2010; 15(1): 64-70.
33. Bachrach LK. Osteoporosis and measurement of bone mass in children and adolescents. Endocrinol Metab Clin North Am. 2005; 34: 521–535.
34. Benefits of Rebounding. Available at http://wellnessmama.com/13915/rebounding-benefits/
35. Witham A, Turton M, Shannon H. The effect of rebound therapy on functional outcomes in children with mild physical impairments. APCP Journal 2012; 3 (1): 49-54
36. Semler O, Fricke O, Vezyroglou K, Stark C, Schoenau E. Preliminary results on the mobility after whole body vibration in immobilized children and adolescents. J Musculoskelet Neuronal Interact. 2007; 7:77–81.
37. Semler O, Fricke O, Vezyroglou K, Stark C, Stabrey A, Schoenau E. Results of a prospective pilot trial on mobility after whole body vibration in children and adolescents with osteogenesis imperfect. Clin Rehab. 2008 ; 22: 387–394
38. Rauch F. Vibration therapy. Dev Med Child Neurol. 2009; 51 (4): 166–168
39. Carr JH, Shepherd RB. Neurological rehabilitation: optimizing motor performance. Oxford : Butterworth Heinemann, 1998.
40. Noyes FR, Dunworth LA, Andriacchi TP, Andrews M, Hewett TE. Knee hyperextension gait abnormalities in unstable knees: Recognition and preoperative gait retraining. Am J Sports Med. 1996; 24(1):35-45.
41. Ulrich S, Hildenbrand FF, Treder U, Fischler M, Keusch S, Rudolf Speich R, et al. Reference values for the 6-minute walk test in healthy children and adolescents in Switzerland. BMC Pulmonary Medicine 2013, 13:49
42. Peredo DE, Hannibal MC. The Floppy Infant: Evaluation of Hypotonia. Pediatrics in Review 2009; 30 (9): e66-e77
43. Root L. Cerebral palsy. In: Pizzutillo PD (ed.). Pediatric orthopedics in primary practice. International edit., New York: McGraw Hill Health Professions Division, 1997: 76-90, 371-379.
44. Rine RM. Management of the pediatric patient with vestibular hypofunction. In: Herdman SJ (ed.). Vestibular Rehabilitation. Philadelphia: F.A. Davis Company; 2007: 360–75.
45. Smith S, Cook D. Rebound Therapy. In: Rennie J (ed). Learning disability- physical therapy treatment and management - A collaborative approach. 2nd ed., John Wiley and Sons: Chichester 2007: 249-262.
46. Palisano RJ, Walter SD, Russell DJ. Gross motor function of children with Down syndrome: creation of motor growth curves. Arch Phys Med Rehabil 2001; 82(4): 494-500.
47. Rosendahl E, Littbrand H, Lindelof N. A high-intensity functional exercise program is applicable for older people with cognitive impairment. Res Pract Alz Dis 2007; 12: 212-5.
48. Vicente-Rodriguez G. How does exercise affect bone development during growth?. Sports Med. 2006, 36(7):561–9.
49. Walker M. Jumping for health. J Appl physiol 2005; 49(5):881-887.
50. Noda R, Maeda Y, Yoshino A. Therapeutic time window for musicokinetic therapy in a persistent vegetative state after severe brain damage. Brain Inj. 2004; 18 (5): 509-15.
51. Wellman T. Ring: resistive aerobic exercise. Total health, 2007. Available at http://www.needak-rebounders.com/Total_Health.htm.
52. Wang WY, Chang JJ. Effects of jumping skill training on walking balance for children with mental retardation and Down syndrome. Kaohsiung J Med Sci. 1997; 13(8): 487-95.
53. Erickson J, Young RO. Rebounding benefits. J Appl physiol. 2009; 49(5): 881-887. Available at http://www.alkalizeforhealth.net/rebounder.htm.
54. Roelants M, Delecluse C, Goris M, Verschueren S. Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. Int J Sports Med. 2004; 25 (1):1–5.

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55. Roelants M, Delecluse C, Verschueren SM. Whole-body-vibration training increases knee-extension strength and speed of movement in older women. J Am Geriatr Soc. 2004; 52:901–8.
56. Verschueren SM, Roelants M, Delecluse C, Swinnen S, Vanderschueren D, Boonen S. Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: a randomized controlled pilot study. J Bone Miner Res 2004; 19:352–359.
57. Cardinale M, Wakeling J. Whole body vibration exercise: are vibrations good for you?. Br J Sports Med. 2005; 39:585–589
58. Torvinen S, Sievanen H, Jarvinen TA, Pasanen M, Kontulainen S, Kannus P. Effect of 4-min vertical whole body vibration on muscle performance and body balance: a randomized cross-over study. Int J Sports Med 2002; 23:374–9
59. Wysocki A, Butler M, Shamliyan T, Kane RL. Whole-Body Vibration Therapy for Osteoporosis. Agency for Healthcare Research and Quality 2011. Available: http:// www.ncbi.nlm.nih.gov › NCBI › Literature › Bookshelf
60. Pitukcheewanont P, Safani D. Extremely Low-Level, Short-Term Mechanical Stimulation Increases Cancellous and Cortical Bone Density and Muscle Mass of Children With Low Bone Density: A Pilot Study. Endocrinologist 2006; 16(3):128-32.
61. Gilsanz V, Wren TAL, Sanchez M, Dorey F, Judex S, Rubin C. Low-level, high-frequency mechanical signals enhance musculoskeletal development of young women with low BMD. J Bone Miner Res. 2006; 21(9):1464-74.
62. Unger M, Jelsma J, Stark C. Effect of a trunk-targeted intervention using vibration on posture and gait in children with spastic type cerebral palsy: a randomized control trial. Dev Neurorehabil. 2013; 16(2):79-88.
63. Eid MA. Effect of Whole-Body Vibration Training on Standing Balance and Muscle Strength in Children with Down Syndrome. Am J Phys Med Rehabil. 201. [PMID: 25299536].
64. Delecluse C, Roelants M, Verschueren S. Strength increase after whole-body vibration compared with resistance training. Med Sci Sports Exerc 2003; 35:1033–41.
65. Straub G. Mini-Trampolines VS Whole Body Vibration Machines, 2012. Available: https://www.facebook.com/GogaStudiosRockford
66. Rebounder vs Whole Body Vibrator - Surprising Results, 2014. Available: http:// doobareviews.com

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