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ORIGINAL ARTICLE

Impact of core stability exercises on bone mineralization and functional capacity in children with polyarticular juvenile idiopathic arthritis: a randomized clinical trial

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Abstract
Background Juvenile idiopathic arthritis (JIA) is the most prevalent rheumatic disease in children. The core stability exercises ensure proper muscular strength and balance around the lumbo-pelvic-hip complex.
Objective This study evaluated whether the use of core stability exercises would increase the effectiveness of conventional physical therapy (PT) in enhancing bone mineralization and improving functional capacity in children with polyarticular JIA.
Methods Thirty-three children with polyarticular JIA (age; 10–14 years) assigned randomly into two groups: the control group ($n = 16$) received the conventional PT, and the study group ($n = 17$) received the core stability exercises in addition to the same conventional PT program. Both core stability and conventional PT exercises continued for 3 months. The measures of bone mineralization and functional ability were investigated by dual-energy X-ray absorptiometry (DXA) device and 6-min walk test (6MWT), respectively, at baseline and immediately post-treatment.
Results Analysis of covariance (ANCOVA) revealed significant differences between groups in favor of the study group regarding measures of bone mineralization of lumbar spine and femoral neck regions as $P < 0.05$, except for volumetric bone mineral density of lumbar spine the $P > 0.05$. There was a significant difference between the two groups concerning functional capacity measured in 6MWT ($P < 0.05$), where children in the study group walked 531.71 ± 90.59 m compared with the control group 509.31 ± 73.10 m.
Conclusion Core stability exercises are an effective adjunctive therapy to enhance bone health status and improve functional capacity in children with polyarticular JIA.

Key Points
- *In addition to conventional physical therapy, core stability exercises had a definite effect on improving bone health status and quality of life in children with polyarticular juvenile idiopathic arthritis.*
- *Improved bone mineralization and functional capacity due to core stability exercises contain two parts: strengthening training and controlling equilibrium.*

Keywords Bone mineral density · Core stability exercises · Juvenile idiopathic arthritis · Polyarticular arthritis

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Introduction

Juvenile idiopathic arthritis (JIA) is the most prevalent rheumatic disease in children [1], with the age of onset before 16 years old and extended for at least 6 weeks, with the highest incidence coming in children below the age of 3 years old [2]. Gender distribution differs according to the disease type, but it is common knowledge that the girls are more affected than boys [3]. It is a complicated systemic disease with unexplored cause involving a generalized failure of the autoimmune system [4]. The persistent inflammation and chronicity of JIA are primary characteristics accompanied by pain, muscle weakness, proprioception dysfunction, diminished physical activity, poor quality of life, and abnormality in bone density [5, 6]. Failure to develop proper bone mineralization is common in children and adolescents with JIA due to chronic inflammation, physical inactivity, muscle weakness, and long-lasting effect of corticosteroids treatment. The result of chronic arthritis on bone health may be soon, resulting in fractures, or it may be later, resulting in decreased suboptimal peak bone mass. Polyarticular and systemic-onset diseases are commonly affected by osteopenia and or osteoporosis than other subtypes [7–9].

The therapeutic exercises are among the treatments available to patients with JIA that include their desired safety. It also aims to reduce pain and improve their quality of life [10]. The core stability exercises, established by McGill, is one of the physical therapy techniques aiming to reduce pain, enhance aerobic capacity, increase muscle strength, and consequently improve the bone health in children with JIA [11]. The phrase "core stability" includes abdominal and oblique muscles anterior-laterally, paraspinal and gluteal muscles posteriorly, diaphragm superiorly, and pelvic floor and hip girdle inferiorly [12]. The core stability exercises could be generally defined as a method to control equilibrium, position, and movement of the trunk over the pelvis and leg in order to produce motion through the terminal segments during activities [13]. A previous study proved that 8-week core stability exercises could improve the strength of transverse abdominis muscle, which in turn increased the trunk strength and endurance [14]. The core stability exercises ensure proper muscular strength and balance around the lumbo-pelvic-hip complex facilitating the production of motion safely and efficiently [15].

A bone-building effect is influenced by strengthening exercises of muscle, especially those exercises which are inducing more significant loading and higher impact activities [16]. Practicing exercises and staying physically active have been considered efficient methods in decreasing bone loss. It is well known that there is a positive correlation between muscle strength and bone mineral density [17]. Core stability exercises may provide several benefits to the musculoskeletal system, associated with isometric or static strength, which in turn may improve bone density [11]. Since loading activities induce an increased percentage of bone mineral density (BMD) more than activities that do not have mechanical loads [18], besides, a little is known about the efficacy of core stability exercises on the bone health status of children with JIA. So, our study aimed to investigate the value of the addition of core stability exercises to conventional physical therapy (PT) in improving bone mineralization and functional capacity in children with polyarticular JIA.

Materials and methods

Study design

This was a randomized, controlled, assessor-blinded clinical trial carried out in accordance with the CONSORT guidelines between September 2018 and November 2019, at the Outpatient Clinic of College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University (PSAU), Saudi Arabia. Bone densitometry and functional status were assessed before and after the intervention by an independent researcher who was not aware of the treatment allocation.

Subjects

Children were recruited from the Pediatric Rheumatology Department, King Khalid Hospital, Al-Kharj, Saudi Arabia. Children were included if were diagnosed with polyarticular JIA according to the International League of Associations for Rheumatology criteria [19], aged from 10 to 14 years, received stable doses of medications, were free of contractures or congenital anomalies, and if they were not advised against participation in exercises by the attending rheumatologist. Exclusion criteria were engagement in regular exercise or sports activities, history of joint surgery, and cardiopulmonary comorbidities.

Assignment procedure

Thirty-six children fulfilled the eligibility criteria. After the baseline assessment, they were allocated randomly into two equal-size groups. The control group ($n = 18$) received the conventional PT, and the study group ($n = 18$) received the core stability exercises in addition to the same conventional PT program. A simple randomization procedure was followed; by drawing sealed non-transparent envelopes, each contains a code for either of the study groups (control or study) by an independent person.

Outcome measures

The primary (bone densitometry) and secondary (functional capacity) outcome measures were assessed by examiners who were blinded to the treatment allocation on two occasions (pre- and post-treatment).

Bone densitometry

The measurement was conducted using LUNAR DPX-L pediatric software dual-energy X-ray absorptiometry (DXA) device (GE-Lunar, Wisconsin, USA). The bone mineral density (BMD; g/cm^2) and bone mineral contents (BMC; g/cm) were evaluated through the lumbar spine (values from L2 to L4) and neck of femur. The BMD z-score was calculated as follows: child's BMD minus BMD from a reference group who were age- and gender-matched divided by the standard deviation of the reference group.

For the lumbar spine, an anteroposterior scan was applied while children were in a supine position with hips and knees flexed at 90° to flatten the lumbar curve. For the femoral neck, children were initially placed in a supine position with both lower limbs slightly abducted in order to preserve the femoral axis straight, then the whole limb internally rotated about (15–30°), and children were instructed to hold very still and to keep from breathing for a few seconds while the x-ray picture is taken to decrease the risk of a blurry image.

To reduce the effect of bone length on the BMD, we computed the volumetric BMD (BMD_{vol}; cm/m^3). We computed the volumetric BMD for the lumbar spine using the following formula: $BMD_{vol} = BMD \times [4 / \pi \times L2\text{–}4 \text{ width in cm}]$ [20]. The BMD_{vol} of the femoral neck was calculated assuming that its shape is cylindrical, and the diameter (d) was given by the software which uses a constant length of $k = 1.5$ cm to measure areal BMD and BMC. The femoral neck diameter was used to estimate the cross-sectional area $[\pi\,(d/2)^2]$ and, therefore, its volume $[\pi\,(d/2)^2 k]$. The BMD_{vol} of the femoral neck was computed as BMC per unit volume, $BMC / [\pi\,(d/2)^2 k]$, or simply as $((BMD)^2/BMC) \times (4k / \pi)$, since measured area estimated as BMC/BMD that is equal to ($k \times d$) [21].

Functional capacity

The 6-min walk test (6MWT) was used to quantify the functional capacity. It is a performance-based test that has been reliably used in children with chronic musculoskeletal disorders to detect the sub-maximal functional capacity [22]. Children were asked to walk forth and back at their usual pace (without running or jogging) to cover up to 6 min as far as possible across an indoor 30-m walkway. Colored cones were placed at both ends of the walkway boundary to indicate turns. Verbal encouragement was given to children every 2 min by the examiner while following them with a stopwatch. At each assessment occasion, each child performed a single test.

Intervention

Conventional physical therapy

In both groups, children received the conventional PT program (30 min/session, three times/week for 3 months). The main concerns were to alleviate pain, maintain/increase flexibility, enhance muscle strength, foster proprioceptive sensation, and promote aerobic capacity. The program generally formed active range of motion exercises, stretching exercises, isometric strength training, weight-bearing exercises, and aerobic exercises on a treadmill or a bicycle according to each child's preference [23–25].

Core stability exercises

Children allocated to the study group received a 45-min lumbar-pelvic/core strength and stability exercise program consisting of eight exercises that have been used in the previous studies on children [26–28] (details are described in Table 1). The program was conducted individually, three sessions/week, for 3 consecutive months under the close supervision of the same pediatric physical therapist. To ensure children's understanding of how each exercise should be performed, they were permitted to overview pictures showing the steps to perform these exercises at the beginning of each session. Intervals of rest were provided as required according to the tolerability of each child. For the safety and optimal performance, all exercises were performed on an exercise mat on the floor.

Sample size calculation

The calculation was performed using G-Power software, V3.0.10 (Neu-Isenburg, Germany). To identify the required sample size, a pilot experiment estimated means (mean 1 = 0.59 and mean 2 = 0.52) and standard deviations (SD1 = 0.06 and SD2 = 0.05) of the BMD of the lumbar spine from L2 through L4. The pilot study consists of eight children who received the same treatments in two groups (four children in each group). Assuming an alpha level of 0.05 and power of 95% in an independent t-test, the sample size of 15 children per each group (total sample-size of 30 children). The sample was increased to 36 children to account for a possible dropout rate of 20%.

Data analysis

Data were analyzed by SPSS, version 23 for windows (SPSS Inc., Chicago, IL). The normality of data distribution was assessed using the Kolmogorov–Smirnov test. The baseline differences between respondents were calculated using independent t test for continuous variables or Mann–Whitney U test and Fishers' exact test for categorical variables. At the post-treatment occasion, the differences between the two groups regarding the dependent outcome measures were analyzed using the analysis of covariance test (ANCOVA). The pre-treatment values of the dependent outcome measures were used as covariates to assess the differences between both groups. The significance level was set at $P < 0.05$ for all statistical tests.

Results

Participants' flow and retention

The CONSORT flowchart depicting the participants' enrollment, randomization, and retention in the present study is shown in Fig. 1. Of 64 children who were initially screened, 36 children were randomized to the study and control groups, and 33 completed the 3-month treatment and post-treatment

Table 1 Core stability exercises applied to the study group

Exercise	Exercise administration	No. repetitions
Crunch core exercises	While children laying supine with their knees bent to 90°, feet flat on the floor, and placing their arms on sides, they were asked to curl their shoulder up of the floor to about 30° angle and hold for 15–30 s while maintaining their back flat on the floor	10 Rs
Supine bridge exercises	While children laying supine with their knees bent to 90°, feet flat on the floor, and placing their arms on sides, they were asked to push down through their feet to lift up the pelvis off the floor to make a straight line with their shoulders and knees and hold for 15–30 s	10 Rs
Plank exercises	While children were assuming a push-up-like position with their weight borne on the forearms and their elbows held directly underneath the shoulder and shoulder-width apart, keeping the trunk straight and legs straight and slightly apart, they were asked to lift their pelvis up off the floor until they were supporting their weight on forearms and toes and to hold for 15–30 s	10 Rs
Quadruped opposite arm/leg exercises	While children were assuming a quadruped position, keeping their heads straight forward, knees bent to 90° and pelvis-width apart, and their hands on the floor shoulder-width apart, children were asked to lift their leg straight while simultaneously lifting the opposite arm and hold for 15–30 s. The same was repeated on the other leg and arm	20 Rs/10 Rs for each side
Prone Opposite arm/leg raise exercise	While children were assuming a prone position with their arms extended over their heads, they were instructed to lift one arm along with their head while simultaneously lifting the opposite leg and holding the position for 15–30 s. The same was repeated on the other arm and leg	20 Rs/10 Rs for each side
Diagonal crunch exercises	While children lying supine with knees bent and both hands clasped behind the head, they were asked to curl right elbow to touch the left knee and then curl left elbow to touch the right knee while simultaneously contracting abdominal muscles	20 Rs/10 Rs for each side
Supine bridge with unilateral leg raise	While children lying supine with knees bent and both on the floor, arms relaxed besides, they were asked to contract abdominal muscles and raise one leg straight up, then raise hips off the floor, and hold for 15–30 s. The same was repeated with the other leg	20 Rs/10 Rs for each side
Side bridge exercises	While children laid on one side with their legs out straight, they were asked to prop themselves up on their elbows so that the elbow was positioned underneath their bottom shoulder and to hold this position for 15–30 s. The top arm was placed on the top hip. Then, they were asked to lift their pelvis up off the floor, aiming to get them aligned with the rest of their bodies. The same was repeated on the other side	20 Rs/10 Rs for each side

measurement: 17 of 18 in the study group (94.4%) and 16 of 18 in the control group (88.9%). The reasons for withdrawal were either unknown (in two children) or a health problem (in one child).

Baseline and demographic data

The baseline demographic and clinical characteristics of the study participants are summarized in Table 2. The study and control groups were homogenous regarding all anthropometric and demographic measures (i.e., age, weight, height, BMI, gender distribution, and pubertal status). The JIA-related clinical features [such as the age of onset ($P = 0.37$), disease duration ($P = 0.28$), rheumatic factor ($P = 0.99$), number of affected joints ($P = 0.07$), pattern of involvement ($P = 0.71$), methotrexate ($P = 0.25$) or corticosteroids dosages ($P = 0.33$), and frequency of steroid injections ($P = 0.26$), disease activity variables (all P values > 0.05), and serum 25-hydroxy vitamin D level ($P = 0.24$)] were also well-balanced between both groups at inception.

Between-groups analysis

Results are shown in Table 3. The central tendency and variability of the data are expressed as mean ± SD. Post-treatment, the analysis of covariance ANCOVA test revealed a significant between-group difference in the measures of lumber spine densitometry adjusted to the pre-treatment values of each, BMD ($F_{(1,30)} = 12.32$, $P = 0.001$), BMC ($F_{(1,30)} = 9.21$, $P = 0.005$), and BMD z-score ($F_{(1,30)} = 6.81$, $P = 0.014$), with exception of the BMD_{vol} ($F_{(1,30)} = 3.29$, $P = 0.08$), where there was no significant difference between the study groups. Regarding the femoral neck densitometry, the analysis showed a significant post-treatment difference between both groups in all measured variables adjusted to the pre-treatment values: BMD ($F_{(1,30)} = 19.96$, $P < 0.001$), BMC ($F_{(1,30)} = 34.09$, $P < 0.001$), BMD z-score ($F_{(1,30)} = 25.73$, $P = <0.001$), and BMD_{vol} ($F_{(1,30)} = 5.63$, $P = 0.024$). Further, the analysis indicated that there was a significant difference between both groups in the distance walked during the 6MWT post-treatment adjusted to the pre-treatment values, where ($F_{(1,30)} = 27.52$, $P = <0.001$).

Discussion

In light of the present results, it is imperative for children who suffer from JIA to be integrated into physical training programs and not to lean in a quiet life that lacks physical activities aiming to maintain and preserve their bone health. This

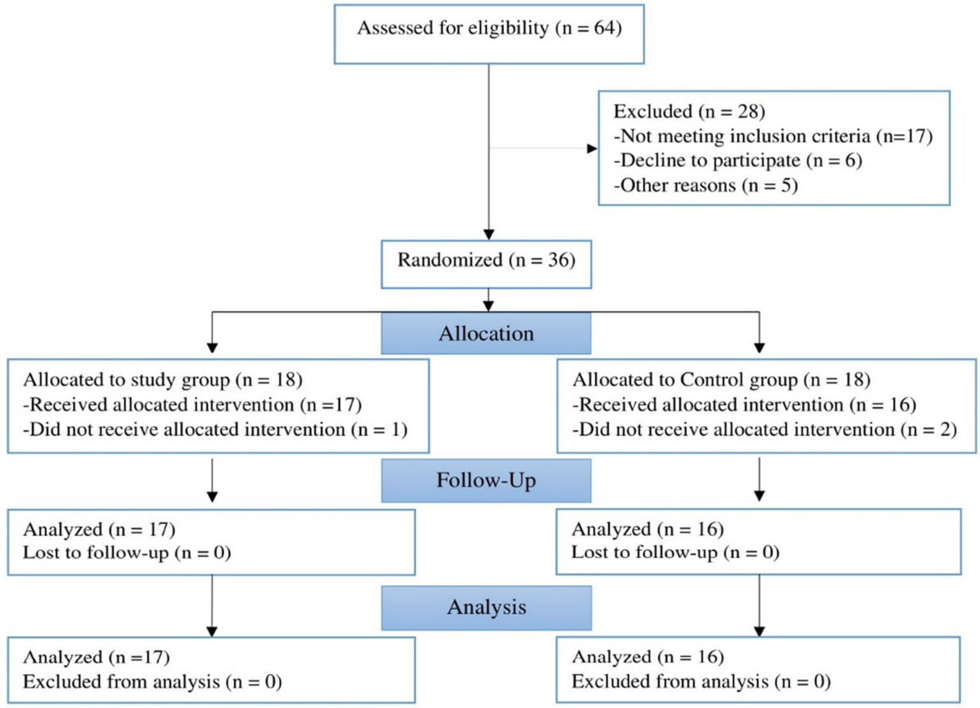

Fig. 1 CONSORT flow diagram

comes in agreement with a previous study that stated that the bone health of children might be affected with a sedentary life in addition to muscular performance and functional abilities, despite the development of medical treatment of arthritic children [29]. The present study showed that of 33 children, girls were affected by 76% (25 girls), and boys were affected by 24% (8 boys), indicating that the female sex was more profoundly affected by JIA. A previous study supported a

Table 2 Participants' clinical and demographic characteristics at the baseline

	Study group ($n = 17$)	Control group ($n = 16$)	P value
Age (year)	12.11 ± 1.65	11.31 ± 1.35	0.14†
Weight (Kg)	35.53 ± 4.47	34.44 ± 3.01	0.42†
Height (m)	1.32 ± 0.06	1.31 ± 0.05	0.68†
BMI (Kg/m^2)	20.18 ± 1.83	19.66 ± 1.30	0.52†
Gender (boys/girls), *n* (%)	5 (29.4)/12 (70.6)	3 (18.7)/13 (81.3)	0.69‡
Pubertal maturation (yes/no), *n* (%)	11 (64.7)/6 (35.3)	6 (37.5)/10 (62.5)	0.17‡
Age at onset (years)	4.59 ± 0.51	4.38 ± 0.81	0.37†
Disease duration (years)	7.53 ± 1.59	6.94 ± 1.48	0.28†
Rheumatic factor (±), *n* (%)	3 (17.6)/14 (82.4)	2 (12.5)/14 (87.5)	0.99‡
Number of affected joints, *n*	8.17 ± 1.29	7.44 ± 0.96	0.07†
Involvement pattern (uni-/bilateral), *n*	4 (23.5)/13 (76.5)	5 (31.3)/11 (68.7)	0.71‡
Medications			
Methotrexate (mg/week)	17.18 ± 4.26	15.56 ± 3.56	0.25†
Corticosteroids (mg qod)	169.71 ± 70.28	147.19 ± 58.17	0.33†
Number of steroid injections, *n*	15.64 ± 7.83	13.12 ± 4.22	0.26†
Disease activity			
Physician global assessment	2 (1–3)	1.5 (1–2)	0.29¥
ESR (mm/h)	25.35 ± 14.90	22.75 ± 10.84	0.57†
Swollen joints, *n*	5 (4–6)	4 (3–5)	0.16¥
Joints with limited ROM, *n*	3 (2–4)	2.5 (2–3)	0.11¥
Serum 25-hydroxy vitamin D (ng/mL)	31.98 ± 8.24	29.11 ± 4.92	0.24†

Continuous data expressed as mean ± SD and categorical data shown as frequency (%). The disease activity variables presented as median (interquartile range) except the ESR presented as mean ± SD. The physician global assessment measures the overall JIA disease activity on a 0–4 scale, where 0 indicates no disease activity and 4 denotes very severe disease. *BMI* body mass index, *ESR* erythrocyte sedimentation rate, *ROM* range of motion

† Independent *t* test

‡ Fishers' exact test

¥ Mann–Whitney *U* test

similar percent in Oman that from a total of 107 children diagnosed with JIA, 77 girls (72%) were affected [30]. Abou El-Soud et al. [31] found an entirely different percentage in a study conducted in Egypt. They reported that 81 girls (61.3%) from a total of 132 children with JIA were affected [31].

Healthy bone status depends on the mechanostat paradigm, which states that healthy bone needs everyday mechanical strains within a limited range to minimize micro-damage of bone and organize the bone formation to meet the functional demands. Many methods achieve this; that exercise training increases muscle strength and consequently exposes the bone to contractile and gravitational forces [32]. The increased BMD and BMC are highly correlated and consequently occurred with improved strong muscles and lean mass [33].

In the present study, it is evident that the children in the study group had a more significant bone health improvement in the femoral neck than in the lumbar spine. Based on the effect size values of this study, we found that all of the bone health measures in the current study, e.g., BMD, improved significantly in the femoral neck region ($P < 0.001$, $d = 0.4$) more than the lumbar spine ($P = 0.001$, $d = 0.29$). Since children of study group engaged in conventional PT and core stability exercises, they showed a more significant improvement of bone health measurements than the control group. A previous study stated that a training program depends on regular or usual exercises without any resistance or high load exercise; the bone cells are less responsive to common loading training [34].

So, in ours, during exercise training in the study group (core stability training plus regular exercises) might be responsible for the high bony response and increased bone health measurements. Similar to ours, however, 30 boys (10–14 years) with hemophilia were conducted and assigned randomly into the study and control group. Static stretching and static contraction for upper and lower limb musculature and aerobic exercises were given to both groups. Besides, the study group children received resistance exercises through bicycling and weight lifting. The treatment program was conducted at three times/week for 3 months, revealing increased BMD in the study group of the femoral neck ($P = 0.01$), proximal tibia ($P = 0.01$), and distal tibia (0.04) more than the control group [35].

Based on the results of the current study, there is an increase in bone strength to the lumbar spine and femoral neck. Since the core stability exercises contain two essential parts, which are strengthening exercises, especially for lumbar and hip regions, and balance exercises, it could have a region-specific effect. Benedetti et al. reported that resistance training with or without loading might be responsible for improving the bone mass and BMD in the specific-stimulated body areas [18]. Furthermore, according to a property of piezoelectric effect, strength training with a high volume and intensity elicits biochemical signals in the bone due to deformation or tension from muscular contractions. Those biochemical signals stimulate cellular action resulting in calcium deposition at stressed and trained spots [36].

Jumping task is considered an essential part of any training program designed for enhancing bone health. A randomized trial conducted by Johannsen revealed that axial loading in the form of jumping (25/day from 45 cm height for 5 days/week lasting for 12 weeks) increased hip and spine BMC and also increased BMDv by 4% in lower limb measured in the tibia

Table 3 Summary of the results of ANCOVA analysis

Dependent variables	Pre-treatment		Post-treatment		Post-treatment difference	
	Study	Control	Study	Control	*P* value	Partial η^2
Lumber spine densitometry						
BMD (g/cm^2)	0.64 ± 0.11	0.63 ± 0.08	0.71 ± 0.06	0.65 ± 0.07	0.001*	0.29
BMC (g/cm)	31.37 ± 6.54	29.93 ± 9.52	36.93 ± 3.70	32.42 ± 7.16	0.005*	0.24
BMD z-score	− 1.12 ± 0.40	− 1.21 ± 0.35	− 0.66 ± 0.34	− 0.94 ± 0.32	0.014*	0.19
BMD$_{vol}$ (g/cm^3)	0.33 ± 0.03	0.31 ± 0.04	0.35 ± 0.02	0.33 ± 0.03	0.08	–
Femoral neck densitometry						
BMD (g/cm^2)	0.64 ± 0.07	0.67 ± 0.05	0.74 ± 0.08	0.69 ± 0.04	< 0.001*	0.40
BMC (g/cm)	32.84 ± 7.98	33.29 ± 6.25	38.92 ± 6.10	34.76 ± 5.08	< 0.001*	0.53
BMD z-score	− 1.30 ± 0.59	− 1.12 ± 0.55	− 0.69 ± 0.30	− 0.99 ± 0.40	< 0.001*	0.46
BMD$_{vol}$ (g/cm^3)	0.32 ± 0.04	0.31 ± 0.05	0.35 ± 0.03	0.32 ± 0.04	0.024*	0.16
Functional capacity						
6MWT (m)	456.59 ± 102.54	493.19 ± 79.03	531.71 ± 90.59	509.31 ± 73.10	< 0.001*	0.48

BMD bone mineral density, *BMC* bone mineral content, *BMD$_{vol}$* bone mineral density volumetric, *6MWT* 6-min walk test. * Significant at $P < 0.05$. Partial η^2, the effect size for significant ANCOVA test

[37]. In the present study, the percent of the increase of BMC in the study group at the lumbar spine and femoral neck regions was 17.7% and 18.5%, respectively. However, the percentage of the rise in BMDv in the study group at the lumbar spine and femoral neck areas, 6% and 9.3%, respectively, was similar to what was stated in Johannsen's study. We attributed the higher increase of BMC in our study compared with Johannsen's study to the combining effect of core stability exercises and weight-bearing exercise.

The plausible improvement of BMD z-score in our study concerning the lumbar spine and femoral neck regions was quite similar, 48.2% and 47% of improvement, respectively. On the contrary, a previous study found negative results after completion of the 6-month home-based exercise program comprising jumping and resistance training assessing lumbar spine bone mass and microarchitecture of distal tibia and radius bone in children with JIA. The results revealed no significant effect of treatment intervention found in the bone mass and structure z-scores [38]. The possible difference between our study and this previous study that prolonged the treatment made it difficult for children to continue and being dropped. So, the authors could not assess adequately the effect of treatment on bone mass and structure in children.

Children with JIA have reduced aerobic capability and functional capacities, which leads to losing the ability to conduct daily activities than do healthy children [6]. Core stability exercises have a definite effect on dynamic functional activity, which is gait. In the present study, 6MWT improved significantly ($P < 0.001$, $d = 0.48$) in the study group, inferring that core stability exercises have an impact on increased strength of lower limb musculature that played a crucial role in walking. Since the core stability exercises contain both types of training; strengthening and balance-proprioceptive training exercises. So, it was acceptable to report in our study that children in the study group showed a significant improvement of functional ability in terms of increased 6MWT measurement (531.71 ± 90.59, meters/6 min) compared with the control group (509.31 ± 3.10, meters/6 min). It is clear that the study group in the current study, which contained strengthening and weight-bearing exercises, as well as core stability exercises that improved the balance, had a positive effect on improving the quality of life as walking. It comes in agreement with Klepper, suggesting that the addition of weight-bearing tasks to balance-proprioceptive exercises encouraged patients readily to become engaged in daily life activities and increased the lower limb musculatures [39].

In our study, the functional abilities of children improved significantly in the form of increasing the covered meters by 16.5% in the study group measured by 6MWT. This finding resulted from an organized exercise program consisting of repetition of each exercise 10 times, three times/week, and extended for 12 weeks. The session time lasted approximately 45 min. A prior study supported this result stating that a well-designed structured exercise training 30–50 min, 2–3 times per week, and extended for 3 to 6 months could decrease the pain and improved the functional capabilities and quality of life in children with JIA [40]. Also, Akuthota et al. stated that the core stability exercises increased the strength of transversus abdominis and internal oblique muscles resulting in increasing the intra-abdominal pressure, enhanced endurance, and increased the firing of gluteus maximus and medius muscles, which contributed by a vital role in stabilizing the trunk and pelvis in the walking activity [41].

Limitations

Although these findings are encouraging, it is worth remarking some limitations of the study. First, although bone densitometry DXA considered the cornerstone in both the diagnosis and monitoring of bone strength and fracture risk, however, besides DXA, the microarchitecture and metabolism of bone could be assessed thoroughly by biochemical markers of bone turnover. They might give a comprehensive view of bone health; but it was difficult to obtain bone biomarkers from children because of challenging circumstances concerning blood samples and preparations. Second, consideration should be given to generalizing the results, so they are specific to one type of JIA that is polyarticular. Further researches are needed to investigate the effect of core stability exercises with conventional PT on different types of JIA. Third, genetics and diet factors might be substantial determinants of BMD.

Conclusion

In conclusion, our results support the use of core stabilization exercises as an effective combined treatment with conventional physical therapy in children suffering from polyarticular JIA, aiming to enhance the bone health status and the functional capacity.

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Authors' contributions Study design: RK and AR; Conduction of the study: RK and SA; Data collection: WS and RK; Data analysis: RK; Data interpretation: RK and WS; Drafting of the manuscript: RK, WS, and AR; Revision of manuscript content: RK and WS; Approval of the final version: RK, WS, AR, and SA

Data availability Not applicable.

Code availability Not applicable.

Compliance with ethical standards

Disclosure None

Ethical approval Details of the study methods were entirely explained for the children and their guardians before enrollment and were invited to sign a consent form. The Ethics Committee of the Physical Therapy Department approved the study (Protocol No: RHPT/18/0049). The study procedures were in compliance with the ethical standards of the Declaration of Helsinki 1964.

References

1. Minden K, Niewerth M, Zink A, Seipelt E, Foeldvari I, Girschick H, Ganser G, Horneff G (2012) Long-term outcome of patients with JIA treated with etanercept, results of the biologic register JuMBO. Rheumatology 51:1407–1415
2. Sullivan DB, Cassidy JT, Petty RE (1975) Pathogenic implications of age of onset in juvenile rheumatoid arthritis. Arthritis Rheum 18: 251–255
3. Ravelli A, Martini A (2007) Juvenile idiopathic arthritis. Lancet (London, England) 369:767–778
4. Petty RE, Southwood TR, Manners P, Baum J, Glass DN, Goldenberg J, He X, Maldonado-Cocco J, Orozco-Alcala J, Prieur AM, Suarez-Almazor ME, Woo P, International League of Associations for Rheumatology (2004) International League of Associations for Rheumatology classification of juvenile idiopathic arthritis: second revision, Edmonton, 2001. J Rheumatol 31:390–392
5. Klepper SE (2008) Exercise in pediatric rheumatic diseases. Curr Opin Rheumatol 20:619–624
6. Takken T (2003) Physical activity and health related physical fitness in children with juvenile idiopathic arthritis. Ann Rheum Dis 62:885–889
7. Burnham JM (2006) Childhood onset arthritis is associated with an increased risk of fracture: a population based study using the General Practice Research Database. Ann Rheum Dis 65:1074–1079
8. McDonagh JE (2001) Osteoporosis in juvenile idiopathic arthritis. Curr Opin Rheumatol 13:399–404
9. Perez MD, Abrams SA, Loddeke L, Shypailo R, Ellis KJ (2000) Effects of rheumatic disease and corticosteroid treatment on calcium metabolism and bone density in children assessed one year after diagnosis, using stable isotopes and dual energy x-ray absorptiometry. J Rheumatol Suppl 58:38–43
10. Singh-grewal D, Wright V, Bar-or O, Feldman BM (2006) Pilot study of fitness training and exercise testing in polyarticular childhood arthritis. Arthritis Rheum 55:364–372
11. McGill SM, Childs A, Liebenson C (1999) Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. Arch Phys Med Rehabil 80:941–944
12. Alsakhawi RS, Elshafey MA (2019) Effect of core stability exercises and treadmill training on balance in children with down syndrome: randomized controlled trial. Adv Ther 36(9):2364–2373
13. Kibler WB, Press J, Sciascia A (2006) The role of core stability in athletic function. Sport Med 36:189–198
14. Hoppes CW, Sperier AD, Hopkins CF, Griffiths BD, Principe MF, Schnall BL, Bell JC, Koppenhaver SL (2016) The efficacy of an eight-week core stabilization program on core muscle function and endurance: a randomized trial. Int J Sports Phys Ther 11:507–519
15. Özekli Mısırlıoğlu T (2018) Does a core stabilization exercise program have a role on shoulder rehabilitation? A comparative study in young females. Turkish J Phys Med Rehabil 64:328–336
16. Cvijetić S, Grazio S, Gomzi M, Krapac L, Nemčić T, Uremović M, Bobić J (2011) Muscle strength and bone density in patients with different rheumatic conditions: cross-sectional study. Croat Med J 52:164–170
17. Iki M, Saito Y, Dohi Y, Kajita E, Nishino H, Yonemasu K, Kusaka Y (2002) Greater trunk muscle torque reduces postmenopausal bone loss at the spine independently of age, body size, and vitamin D receptor genotype in Japanese women. Calcif Tissue Int 71:300–307
18. Benedetti MG, Furlini G, Zati A, Letizia Mauro G (2018) The effectiveness of physical exercise on bone density in osteoporotic patients. Biomed Res Int 2018:1–10
19. Hofer M (2002) Classification of childhood arthritis. Best Pract Res Clin Rheumatol 16:379–396
20. Susic G, Stojanovic R, Damjanov N, Vojinovic J, Vijatov G (2008) Bone mineral density improvement after one year of treatment with etanercept in patients with juvenile idiopathic arthritis. Pediatr Rheumatol Online J 6:P90–P90
21. Kröger H, Kotaniemi A, Vainio P, Alhava E (1992) Bone densitometry of the spine and femur in children by dual-energy x-ray absorptiometry. Bone Miner 17:75–85
22. Elnaggar R, Mohammed R, Abdelhalim N, Samhan A (2015) A rehabilitation program recommendation for children with juvenile psoriatic arthritis. Int J Ther Rehabil Res 4:1
23. Elnaggar RK, Elshafey MA (2016) Effects of combined resistive underwater exercises and interferential current therapy in patients with juvenile idiopathic arthritis. Am J Phys Med Rehabil 95:96–102
24. Azab RA, Hamed SA, Abdel Halim AS (2018) Effect of Kinesio taping on balance in children with juvenile idiopathic arthritis. Life Sci J 15:104–110
25. Azab A (2016) Effect of extracorporeal shockwave therapy on selected gait parameters in children with juvenile idiopathic arthritis. Int J Ther Rehabil Res 5:180
26. Rahmat A, Naser H, Belal M, Hasan D (2014) The effect of core stabilization exercises on the physical fitness in children 9-12 years. Med Sport 3:2401–2405
27. Aly SM, Abonour AA (2016) Effect of core stability exercise on postural stability in children with Down syndrome. Int J Med Res Heal Sci 5:213–222
28. Rahmat A, Hasan D (2013) The effect of core stabilization exercises on factors physical fitness to mental retardation. Sport Med J Med Sport 9:2058–2062
29. Sandstedt E, Fasth A, Fors H, Beckung E (2012) Bone health in children and adolescents with juvenile idiopathic arthritis and the influence of short-term physical exercise. Pediatr Phys Ther 24: 155–161
30. Abdwani R, Abdalla E, Al Abrawi S, Al-Zakwani I (2015) Epidemiology of juvenile idiopathic arthritis in Oman. Pediatr Rheumatol 13:13–18
31. Abou El-Soud AM, El-Najjar AR, El-Shahawy EE, Amar HA, Hassan TH, Abd-Allaha SH et al (2013) Prevalence of juvenile idiopathic arthritis in Sharkia Governorate, Egypt: epidemiological study. Rheumatol Int 33:2315–2322
32. Going SB, Farr JN (2010) Exercise and bone macro-architecture: is childhood a window of opportunity for osteoporosis prevention? Int J Body Compos Res 8:1–9
33. Guimarães BR, Pimenta LD, Massini DA, Dos Santos D, Da Cruz Siqueira LO, Simionato AR et al (2018) Muscle strength and regional lean body mass influence on mineral bone health in young male adults. PLoS One 13:1–13
34. Lanyon LE (1996) Using functional loading to influence bone mass and architecture: objectives, mechanisms, and relationship with estrogen of the mechanically adaptive process in bone. Bone 18:S37–S43
35. Eid MA, Ibrahim MM, Aly SM (2014) Effect of resistance and aerobic exercises on bone mineral density, muscle strength and

functional ability in children with hemophilia. Egypt J Med Hum Genet 15:139–147
36. Cadore EL, Brentano MA, Kruel LFM (2005) Effects of the physical activity on the bone mineral density and bone remodelation. Rev Bras Med Esporte 11:373–379
37. Johannsen N, Binkley T, Englert V, Neiderauer G, Specker B (2003) Bone response to jumping is site-specific in children: a randomized trial. Bone 33:533–539
38. Houghton KM, Macdonald HM, McKay HA, Guzman J, Duffy C, Tucker L et al (2018) Feasibility and safety of a 6-month exercise program to increase bone and muscle strength in children with juvenile idiopathic arthritis. Pediatr Rheumatol 16:1–13
39. Klepper SE (1999) Effects of an eight-week physical conditioning program on disease signs and symptoms in children with chronic arthritis. Arthritis Care Res 12:52–60
40. Klepper S, Mano Khong TT, Klotz R, Gregorek AO, Chan YC, Sawade S (2019) Effects of structured exercise training in children and adolescents with juvenile idiopathic arthritis. Pediatr Phys Ther 31:3–21
41. Akuthota V, Ferreiro A, Moore T, Fredericson M (2008) Core stability exercise principles. Curr Sports Med Rep 7:39–44

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