Original Article

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Effect of Circuit Training on Calcium Level and Physical Fitness in Pregnant Women with Hypocalcemia: A randomized controlled trial

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Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract: *Background:* Hypocalcemia is a common problem during pregnancy that affects maternal and fetal outcomes. So, preventive and treatment measures are warranted to prevent complications and promote health and well-being in pregnant women with calcium deficiency. *Purpose:* This study aimed to investigate the effect of circuit training (CT) on calcium levels and physical fitness in pregnant women with hypocalcemia. *Methods:* Forty-four pregnant women in their 2nd trimester having hypocalcemia participated in the study; their ages ranged from 20 to 35 years old, and their body mass index (BMI) was 35.00 to 39.99kg/m^2. They were randomly divided into two equal groups. The control group received daily calcium supplements (1.5 – 2 g), while the CT group received the same tablets and performed the CT program for 60 minutes, three sessions per week for 12 weeks. Serum-free and ionized calcium levels were measured, and sit and reach flexibility test, wall squat test, chair stand test, and modified push-up test assessed the physical fitness before and after treatment. *Results:* The control and CT groups showed statistically significant increases ($p<0.0001$) in free and ionized calcium levels and a non-significant difference ($p>0.05$) between groups after treatment. Compared to the control group, the CT group showed statistically significant increases ($p<0.0001$) in the scores of sit and reach flexibility test, wall squat test, chair stand test, and modified push-up test after treatment. However, the control group showed a non-significant difference ($p>0.05$) in all test scores. *Conclusion:* Adding CT to calcium supplements is a safe and effective method that maintains calcium and improves physical fitness in pregnant women with hypocalcemia, which should be a part of the antenatal exercises program for gravid women.

Keywords: pregnancy, hypocalcemia, circuit training, calcium, physical fitness

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INTRODUCTION

Hypocalcemia is a metabolic problem occurring during pregnancy; it results from calcium loss from circulation or insufficient calcium entry into the circulation. It occurs in cases of hypoparathyroidism and mothers with severe dietary inadequacy [1,2]. The prevalence of hypocalcemia is high in low and middle outcomes countries [3]. It is about 66.4% in India [4], 70.55% in Algeria [5], and 64.8% in Egypt [6].

During pregnancy, numerous physiological changes increase the volume of plasma and red blood cells while decreasing the number of micronutrients and circulating nutrient-binding proteins. Poor nutrition with typical physiologic pregnancy changes can cause micronutrient-deficient states [7]. Also, hem-dilution, which occurs during pregnancy, causes serum albumin and hemoglobin to decrease; the reduced albumin causes the total serum calcium to drop to levels generally associated with symptomatic hypocalcemia [1].

Hypocalcemia can result in many complications ranging from mild to severe depending upon the duration and severity of the condition. Muscle spasms, cramping, and tingling or numbness in the fingers, toes, or mouth area occur in mild cases. Also, it can cause seizures, cardiac arrhythmias, and even cardiac arrest in more severe cases. Additionally, osteoporosis, brittle bones, and an elevated risk of fractures can develop from chronic hypocalcemia [8].

Treating hypocalcemia is crucial to prevent complications and promote maternal and fetal health and well-being. Pregnant women, particularly those with low dietary calcium intake (<500 mg), benefit from the recommended daily calcium supplementation. It reduces the risk of pre-eclampsia, gestational hypertension, and preterm birth and improves fetal bone mineralization [1,9].

Exercise helps in increasing calcium levels. It plays a significant role in increasing bone density by transmitting mechanical force to the bone, stimulating intracellular processes in bone tissue, and increasing the deposition of minerals in the bone [10,11]. Regular exercise among healthy pregnant women has shown increases in 25(OH)D, free 25(OH)D, and bioavailable 25(OH)D with no adverse effects on calcium and corrected calcium [12].

Circuit training (CT) is a type of physical conditioning that includes exercises done in a circuit, resistance training, high-intensity aerobics, and endurance training. It involves activities for the upper body, core, trunk, and lower body [13]. It is recommended as an effective method for improving muscle strength, body composition, and cardiorespiratory fitness [14,15]. In addition, a high-intensity interval training resistance circuit has proved to be a safe exercise modality in the second and third trimesters of pregnancy, inducing no adverse effects on fetal outcomes. However, further studies are warranted [16].

To the authors' knowledge, the impact of CT on calcium levels and physical fitness in pregnant women with hypocalcemia was still unknown. Therefore, this study aimed to determine the effect of combined CT and calcium supplementation on ionized and free calcium levels and physical fitness in pregnant women with hypocalcemia. This study hypothesized that combined calcium supplements and CT would influence pregnant women's calcium levels and physical fitness more than calcium supplementation alone.

MATERIAL AND METHODS

Participants

This study was a prospective randomized controlled trial. Healthy primigravida women in the second trimester (18^{th} to 24^{th}) weeks of gestation participated in this study. An obstetrician recruited all pregnant women from the Outpatient Gynecology and Obstetrics Clinic. They were diagnosed with calcium deficiency; they had ionized calcium levels below 4.6 mg/dL (1.15 mmol/I) [17]. Also, they experienced low dietary calcium intake (<500 mg), which was confirmed by the food frequency questionnaire [18].

Their ages ranged from 20 to 35 years old, and their body mass index (BMI) ranged from 35.00 to 39.99 Kg/m^2. The exclusion criteria included pregnant women having severe anemia, uncontrolled diabetes mellitus, gestational diabetes, pre-eclampsia, preterm labor, or those with a history of habitual abortion, thyroid, kidney, and liver dysfunction, cardiovascular diseases, chronic obstructive pulmonary diseases, or malignancy.

Sample size calculation

G*POWER statistical software (version 3.1.9.2) was the tool to calculate the sample size. The calculation depended on obtained ionized calcium data from a pilot study on three subjects per group. The analysis revealed that the required sample size for this study was 22 subjects per group using $\alpha=0.05$, power 80%, effect size=0.8387, and allocation ratio N2/N1 =1.

Randomization and blinding

In this study, the obstetrician assessed 49 participants for eligibility; three women failed to meet the inclusion criteria, and two refused to participate. The 44 participants were available for randomization.

A blinded researcher to the study treatment developed computer-generated randomization cards using a statistical package for social science (SPSS), version 23 (Armonk, NY: IBM Corp). Then, he opened sealed envelopes and assigned the participants to the control or study group according to the chosen cards. The control group received a daily dosage of calcium supplements (1.5-2 g/ day) for 12 weeks as prescribed by the obstetrician. The CT group received the same prescribed calcium supplements and performed CT, three sessions/week for 12 weeks. All participants in both groups were available for follow-up and included in the analysis. All pregnant women signed the consent form after explaining the study's aims and nature and informing them about their rights to withdraw at any time.

1. Outcome measures

A. Calcium levels assessment

After a 12-hour fast, five ml of venous blood was collected from each pregnant woman at 9 a.m. The collected blood was centrifuged at 3000 rpm for 10 minutes after being clotted in a container. Whenever possible, the samples were analyzed immediately or stored at -20° Celsius till further analysis. Ionized calcium and free calcium levels were estimated using the o-Cresolphthalein Complexone assay method before and after 12 weeks of the treatment [19].

B. Physical Fitness level assessment:

A blinded examiner assessed the physical fitness level using sit and reach flexibility test, wall squat test, chair stand test, and modified push-up test for each pregnant woman before and after 12 weeks of the study course.

Sit and reach flexibility test

It assessed the flexibility of the lower back and hamstring muscles. Each woman sat on the floor with her legs outstretched and the testing box placed in front of her; she pointed her fingers at the level of 0 cm of the ruler placed on top of the box; she moved forward as far as she could while keeping her extended knees and hold that position for two seconds to allow recording the distance in centimeters [20].

Wall squat test

It assessed the strength of the quadriceps muscle. Each woman stood comfortably with her back against a smooth wall, slid down the wall until her hip and knee formed a 90-degree, and elevated one foot 5 cm off the ground holding the position as long as she could. She repeated the test with the other leg. The examiner recorded the average time for elevating both feet in seconds [21].

Chair stand test

It assessed leg strength and endurance. Each pregnant woman sat in the middle of a seat with her feet flat on the floor and arms crossed at the chest; the examiner asked her to stand up and sit down for 30 seconds and then recorded the total number of complete chair stands [22].

Modified push-up test.

It assessed upper body muscular endurance containing the shoulders, chest, and back of the upper arms. Each pregnant woman assumed a prone kneeling position with flexed knees, feet together and up to twelve inches apart, and hands placed approximately shoulder width apart with fingers facing forward. She bent the elbows to 90 degrees keeping a straight line from the toes to the hips to the shoulders. She performed the test until she was not able to continue. The examiner recorded the total number of complete modified push-ups [23].

2. Intervention

A. Calcium supplements

All pregnant women received calcium tablets (1.5-2 g/day) as the obstetrician prescribed. A previous systematic review recommends daily calcium supplementation, particularly for those with low dietary calcium intake, because it improves maternal and fetal outcomes [9]. All women maintained their diet intake during the study course.

B. Circuit training (CT) program

The CT program was consistent with the American College of sports medicine (ACSM) guidelines [22]. The program consisted of warm-up, active, and cool-down phases. The warm-up phase was about 5-10 minutes and included brisk walking followed by gentle stretching exercises to improve flexibility and range of motion. The cool-down phase consisted of 5-10 minutes of walking followed by static stretching exercises to help lower heart rate, return body temperature to normal, facilitate recovery, and reduce muscle soreness.

The active phase consisted of a circuit of aerobic and resistance exercises, with equal time to each, for a 45-minute workout. The pregnant women rotated between 4.5 minutes of aerobic and resistance training exercises for five circuits. The exercise program included back extension, abdominal curl, seated row, leg curl, leg extension, leg press, latissimus pull down, and standing calf raise. In back extension exercises, each woman extended her back as much as possible from the standing position and returned to the starting position. In abdominal curl, she assumed a crook lying position, lifted off the upper body as high as possible, and lowered back down. She performed seated row exercises from long sitting while gripping the TheraBand that anchored the feet bottom; she pulled the TheraBand towards her body by flexing her elbows and then released the band back. In leg curl exercises, she assumed a standing position, bent one knee towards her buttock, and extended her leg. She practiced leg extension exercises while sitting on a chair; she straightened one leg in front to achieve maximum knee extension and flexed her knees to the starting position. She performed leg press exercises while lying supine on a mat with flexed hips and knees and holding a band that rounded her feet; she pushed the TheraBand away from her body by extending her legs and bending them to the starting position. She practiced latissimus pull-down exercises in standing with extended elbows and hands gripping the TheraBand above the head. She flexed her elbows, pulled the TheraBand down behind her head, and extended her elbows back. In standing calf raises exercises, she lifted her heels from the ground as high as possible and then lowered the heels back to the floor.

The pregnant woman practiced the resistance training using the TheraBand black band (4-18 pounds); she performed each exercise ten times for one to two sets in the first month and eight times for three sets in the second month. Finally, repetition reached ten times for three sets in the third month. The resistance was increased by 10% each week according to ACSM exercise guidelines. She carried out the exercise program three days/week [24,25].

The physical therapist measured blood pressure before and after each exercise session and monitored the heart rate during exercises to maintain the pregnant woman's target heart rate zones. The exercise intensity was 60%-80% of the heart rate reserve, which nearly did not exceed a heart rate of 140 beats per minute [26]. The rating of perceived exertion was somewhat hard (13–14) on the Borg rating scale, and the talk test was the method used for monitoring the exercise intensity [27].

Statistical analysis

The data were analyzed using the SPSS software package version 20.0 (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov test was the method used to ensure the normality of distribution. Descriptive statistics such as mean and standard deviation summarized the quantitative data. The independent t-test compared between groups data, and the dependent t-test compared within groups data. P-value <0.05 was significant.

RESULTS

Table 1 included participants' baseline characteristics of the control and CT groups. The unpaired t-test showed no significant differences in the mean age (p=0.77), weight (p=0.91), height (p=0.68), BMI (p=0.45), gestational age (p=0.67), and FFQ score (p=0.99). Paired t-test revealed that free and ionized calcium levels increased significantly (p<0.0001) within the control and CT groups post-treatment. However, the unpaired t-test showed no significant differences between groups in free (p=0.69) and ionized calcium (p=0.62) levels post-treatment (table 2). Paired t-test showed no statistically significant changes in the scores of the sit and reach test (p=0.68), wall squat test (p=0.61), chair stand test (p=0.64), and modified push-up test (p=0.85) in the control group post-treatment. While for the CT group, there were statistically significant increases (p<0.0001) in the scores of all tests post-treatment. Also, the unpaired t-test showed statistically significant increases (p<0.0001) in the scores of all tests in the CT group compared to the control group post-treatment, as included in Table 3.

Table 1. Participants' baseline characteristics of the control and CT groups.

Variable	Control group	CT group	MD	T-value	P-value
	Mean ± SD	Mean ± SD			
Age (years)	24.77±3.31	24.5±2.89	0.27	0.77	0.77 NS
Weight (kg)	94.95±6.99	95.18±7.71	0.23	0.91	0.91 NS
Height (cm)	160±5.00	161±5.00	1.00	0.68	0.68 NS
BMI (kg/m^2)	36.95±1.27	37.27±1.55	0.32	0.45	0.45 NS
Gestational age	20.95±2.10	20.68±2.12	0.27	0.67	0.67 NS
FFQ score	366.95±42.10	370.14±41.73	-3.19	0.99	0.99 NS

SD: Standard deviation; MD: Mean difference; P-value: Probability value; BMI: body mass index; CT: circuit training; FFQ: food frequency questionnaire; NS: non-significant.

Table 2. Within and between group analysis of free and ionized calcium level in the control and CT groups.

Measure	Indicator	Control group	CT group	MD	T value	P-value
		Mean±SD	Mean±SD			
Free calcium (mg/dL)	Pre-treatment	1.81±0.63	2.10±0.53	0.29	1.63	0.10 NS
	Post-treatment	2.92±0.59	3.01±0.56	0.09	0.50	0.69 NS
	MD	1.11	0.91			
	% of change	61.32	43.30			
	T value	6.00	5.55			
	P-value	<0.0001*	<0.0001*			
Ionized calcium level (mmol/l)	Pretreatment	0.75±0.12	0.80±0.12	0.05	1.33	0.20 NS
	Post-treatment	1.46±0.27	1.50±0.30	0.04	0.65	0.62 NS
	MD	0.71	0.70			
	% of change	94.60	87.50			
	T value	11.32	10.13			
	P-value [a]	<0.0001*	<0.0001*			

SD: Standard deviation; MD: Mean difference; P-value: Probability value; CT: circuit training; NS: non-significant; * significant at p<0.05.

Table 3. Within and between group analysis of physical fitness test scores for the control and CT groups.

Measure	Indicator	Control group	CT group	MD	T value	P-value
		Mean±SD	Mean±SD			
Sit and reach flexibility test (cm)	Pre-treatment	64.05±10.04	66.32±9.58	2.27	0.76	0.41 NS
	Post-treatment	62.77±9.54	75.64±5.31	12.87	5.52	<0.0001*
	MD	1.28	9.32			
	% of change	1.99	14.05			
	T value	0.43	3.98			
	P-value	0.68 NS	<0.0001*			
Wall squat test (sec)	Pre-treatment	13.82±3.32	15.18±3.14	1.36	1.40	0.97 NS
	Post-treatment	14.09±3.1	26±6.20	11.91	8.06	<0.0001*
	MD	0.27	10.82			
	% of change	1.95	71.27			
	T value	0.38	7.30			
	P-value	0.61 NS	<0.0001*			
Chair stand test (count)	Pre-treatment	8.95±2.08	8.36±1.53	0.59	1.07	0.42NS
	Post-treatment	9.18±1.87	11.82±2.11	2.64	4.39	<0.0001*
	MD	0.23	3.46			
	% of change	2.56	41.38			
	T value	0.38	6.22			
	P-value	0.64 NS	<0.0001*			
Modified push up test (count)	Pre-treatment	2.45±1.79	2.32±1.76	0.13	0.25	0.91NS
	Post-treatment	2.55±1.68	5.91±1.27	3.36	7.48	<0.0001*
	MD	0.10	3.59			
	% of change	4.08	154			
	T value	0.17	7.77			
	P-value [a]	0.85 NS	<0.0001*			

SD: Standard deviation; MD: Mean difference; P-value: Probability value; CT: circuit training; NS: non-significant; * significant at p<0.05.

DISCUSSION

Pregnancy is a time of significant physiological changes, including alterations in body composition, metabolism, and hormonal levels. The low calcium intake and increased demand for calcium for fetal development and growth may increase the risk of hypocalcemia in pregnant women. Hypocalcemia affects maternal bone and muscles resulting in adverse maternal and fetal outcomes [28]. Maintaining normal calcium and physical fitness levels during pregnancy is essential for maternal and fetal health [29], so this study aimed to investigate the effect of CT on calcium levels and physical fitness in pregnant women with hypocalcemia.

The results showed significant increases in free and ionized calcium levels in the group receiving calcium supplementations only and the CT group without significant differences between groups after treatment. These findings agreed with a previous study, which reported that daily calcium supplementations may benefit pregnant women, particularly those with low dietary calcium intake [9].

The current results showed no significant difference between both groups in all calcium measures, which agreed with Gustafsson et al.; they have reported that regular exercise has no effects on calcium and corrected calcium in healthy pregnant women [12].

There were several suggestions to explain why CT may not affect calcium levels in pregnant women; the first one is that any changes in calcium metabolism induced by exercise may be localized to the active muscle tissue and not be reflected as changes in the systemic calcium levels [30]; secondly, hormonal changes associated with pregnancy may mask any differences in calcium levels induced by exercise [31]; thirdly, exercise may affect the secretion of hormones such as parathyroid hormone and calcitonin, which regulate calcium metabolism [32], and may mediate the effects of CT on calcium levels; fourthly, increased urinary calcium excretion after strenuous exercise may occur due to decreased renal calcium reabsorption because of exercise-induced metabolic acidosis. An imbalance between urinary Ca excretion and Ca release from bone may induce a net reduction in serum-ionized calcium levels [33]. But parathyroid hormone, calcitonin, and urinary Ca are not investigated in the present study and need further research to confirm these suggestions. Finally, the exercise program's duration or intensity may not be enough to elicit a measurable effect on calcium levels. A longer or different-intensity exercise program may be necessary to observe changes in calcium levels.

Additionally, the CT group showed a significant increase in physical fitness, as assessed by the sit and reach flexibility test, wall squat test, chair stand test, and modified push-up test without changes in the control group; improved tests score reflected the increased upper and lower limbs muscles strength and endurance, as well as improved flexibility of the lower back and hamstring muscles of the pregnant women. The present results agreed with a previous study, which showed that a 12-week CT contributed to improved muscular strength, cardiovascular endurance, and flexibility in middle-aged women [34] and aerobic capacity and muscular strength in older adults [14]; another study reported that a supervised circuit-style resistance-training program over 14 weeks promoted significant improvements in strength, peak aerobic capacity, and blood lipids [35].

Resistance exercise causes fiber hypertrophy, alters oxygen transport, increases capillary density per fiber, and improves the muscle cell's ability to oxidize substances, as evidenced by increased citrate synthase activity [36]; all may induce increased physical fitness observed in pregnant women after CT.

CT with less weight may not improve strength compared to traditional weight training, as large loads are essential for maximum gains in muscular power [37]; however, CT has a lower rate of energy expenditure than other forms of exercise [38] and is pleasurable, simple, easy, and safe to practice at home.

Strengths and limitations:

It is the first study that investigated the effect of CT on calcium and physical fitness levels in pregnant women with hypocalcemia. There are some limitations to consider. The underlying mechanisms for the CT effect on calcium levels and physical fitness are still unknown; this study did not monitor the parathyroid hormone, vitamin D levels, calcitonin, and urinary calcium, which interfere with calcium levels. So further studies are needed to investigate the CT effect on these hormones during pregnancy. Using subjective methods for assessing physical fitness is another limitation. Therefore, more studies are essential to investigate the training effect with more objective evaluative procedures for physical fitness levels in pregnant women with hypocalcemia. Also, there is a need for comparative studies to explore the outcome of different types and intensities of exercises on pregnant women. Moreover, the CT's long-term impact on a large sample size of pregnant women is warranted to be studied.

CONCLUSION

Adding CT to calcium supplements is an effective treatment that maintains calcium and improves physical fitness levels in pregnant women with hypocalcemia. It should be a part of the antenatal exercise program for gravid women.

Declarations: All authors declare that they do not have any conflict of interest.

Ethical approval and clinical trial registration: Ethical approval was obtained from the institutional review board (No: P.T.REC/012/003729) before starting of the study. The research followed the guidelines of the Declaration of Helsinki for human conduct. The protocol was prospectively registered at clinical trial at clinicaltrial.gov (NCT05469763). Each pregnant woman signed the consent form after explaining the study aims, nature, and procedures, and informing them about their rights to withdraw at any time.

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