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Effectiveness of plyometrics vs. circuit training in core conditioning: an empirical study

Eficacia del entrenamiento pliométrico vs. el entrenamiento en circuito en la condición del core: un estudio empírico

Pramod Ravi, Divya Kalimuthu
Alagappa University, India.

*Correspondence Author: Pramod Ravi pramodrviis@gmail.com

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Abstract

Core conditioning is vital to athletic training to enhance stability, endurance, and functional strength. This study investigates the effectiveness of circuit and plyometric training in improving abdominal endurance and core strength. Sixty male participants, with an Age: 15.75 ± 0.69, Height: 172.21±5.02, Weight: 84.79±6.17 and BMI: 28.79±1.58 were randomly assigned to one of three groups: the Plyometric Training Group (PTG), the Circuit Training Group (CTG), or the Control Group (CG). Over 12 weeks, the PTG engaged in explosive plyometric exercises specifically targeting the core, while the CTG participated in structured circuit-based core workouts. Pre-test and post-test evaluations were conducted to assess abdominal endurance through the sit-up test and core strength via the plank test. The results revealed significant improvements in both experimental groups, with the PTG demonstrating greater core strength and endurance advancements compared to the CTG and CG. Statistical analysis, conducted using ANCOVA, indicated a highly significant difference ($p < 0.05$) in post-test scores among the groups, affirming the effectiveness of both training modalities. Remarkably, plyometric training produced slightly greater neuromuscular adaptations, underscoring its potential to enhance core performance. These findings advocate incorporating structured plyometric and circuit training regimens into athletic and general fitness programs to optimise core development.
Keywords: abdominal endurance, core strength, plank test, neuromuscular adaptation, athletic performance.

Resumen

El acondicionamiento del core es vital en el entrenamiento deportivo para mejorar la estabilidad, la resistencia y la fuerza funcional. Este estudio investiga la eficacia del entrenamiento en circuito y el entrenamiento pliométrico para mejorar la resistencia abdominal y la fuerza del core. Sesenta participantes masculinos, con una edad promedio de 15,75 ± 0,69 años, una altura de 172,21 ± 5,02 cm, un peso de 84,79 ± 6,17 kg y un IMC de 28,79 ± 1,58, fueron asignados aleatoriamente a uno de tres grupos: el Grupo de Entrenamiento Pliométrico (PTG), el Grupo de Entrenamiento en Circuito (CTG) o el Grupo de Control (CG). Durante 12 semanas, el PTG realizó ejercicios pliométricos explosivos dirigidos específicamente al core, mientras que el CTG participó en entrenamientos estructurados de core basados en circuitos. Se llevaron a cabo evaluaciones pretest y postest para medir la resistencia abdominal mediante la prueba de abdominales (sit-up test) y la fuerza del core a través de la prueba de plancha (plank test). Los resultados revelaron mejoras significativas en ambos grupos experimentales, siendo el PTG el que mostró mayores avances en fuerza y resistencia del core en comparación con el CTG y el CG. El análisis estadístico, realizado mediante ANCOVA, indicó una diferencia altamente significativa ($p < 0.05$) en los resultados postest entre los grupos, lo que confirma la efectividad de ambas modalidades de entrenamiento. Notablemente, el entrenamiento pliométrico produjo adaptaciones neuromusculares ligeramente superiores, lo que resalta su potencial para mejorar el rendimiento del core. Estos hallazgos apoyan la incorporación de programas estructurados de entrenamiento pliométrico y en circuito en los programas de acondicionamiento físico general y deportivo para optimizar el desarrollo del core.
Palabras clave: resistencia abdominal, fuerza del core, prueba de plancha, adaptación neuromuscular, rendimiento atlético.

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Introduction

Circuit training represents a dynamic and versatile exercise methodology that has gained substantial popularity due to its effectiveness in enhancing cardiovascular endurance, muscular strength, and overall fitness(Vadivel & Maniazhagu, 2022; Wang & Zhang, 2016). This training approach consists of a sequence of exercises performed in succession with minimal rest intervals between stations, resulting in a high-intensity workout that engages multiple muscle groups (Adamson, 1959; T. O. Bompa et al., 2012; Riva et al., 2016). The adaptability of circuit training makes it suitable for individuals across a spectrum of fitness levels, from novices to professional athletes (Toppo, 2024). It can be executed using bodyweight exercises, free weights, resistance bands, or specialised gym equipment, depending on the specific objectives of the training session (Baechle & Earle, 2019). Circuit training has undergone significant evolution, incorporating various techniques such as High-Intensity Interval Training (HIIT) (Dahlan & Alimuddin, 2019), strength circuits, and sport-specific routines (Mahalingam et al., 2024). A notable advantage of circuit training is its capacity to simultaneously enhance muscular strength and cardiovascular fitness (Ravi & K, 2024; Sonchan et al., 2017). In contrast to traditional workout regimens that typically isolate either strength training or aerobic exercises, circuit training integrates both components into a cohesive workout (T. O. Bompa et al., 2012). This dual-action approach improves endurance and promotes muscular development, ultimately contributing to superior overall athletic performance (Tong et al., 2024). Furthermore, circuit training is optimal for individuals seeking to maximise calorie expenditure, as continuous movement and elevated heart rate facilitate increased energy burn during and after the workout (Benson & Connolly, 2019; T. Bompa & Buzzichelli, 2021).

Another highly effective training modality that complements circuit training is plyometric training. Plyometric exercises involve explosive movements that enhance power, speed, and neuromuscular efficiency (Almoslim, 2016). Common plyometric exercises include box jumps, jump squats, bounding drills, and clap push-ups (Deng et al., 2023). These movements utilise muscles' stretch-shortening cycle, allowing them to produce more significant force in a shorter timeframe (Fortuna et al., 2018). Plyometric training is extensively utilised in sports conditioning, particularly in disciplines that

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require rapid acceleration, jumping capability, and swift directional changes (Comfort et al., 2024; Myer et al., 2006). A significant benefit of incorporating plyometric exercises into a circuit training program is enhancing functional strength and movement efficiency (Utomo et al., 2024). The rapid, high-impact nature of plyometric training promotes the development of fast-twitch muscle fibers, essential for generating explosive power and agility (Booth & Orr, 2016). By integrating plyometric movements into a circuit framework, athletes can enhance their athletic performance while benefiting from the endurance advantages of circuit-based workouts (Falk Neto & Kennedy, 2019).

Circuit and plyometric training are essential components in enhancing abdominal endurance and core strength. Numerous circuit and plyometric routines incorporate core-focused exercises, including planks, Russian twists, mountain climbers, and bicycle crunches, to enhance stability, balance, and functional movement (Wijaya et al., 2024). Engaging the core throughout a workout strengthens the abdominal muscles, improves posture, reduces the risk of lower back pain, and enhances overall athletic performance (Kim & Yim, 2020). Plyometric exercises, such as medicine ball slams, tuck jumps, and lateral hops, require considerable core engagement, strengthening core endurance and stability during high-impact movements (Branet et al., 2020).

Plyometric training can be strategically incorporated into a circuit by integrating explosive exercises between strength and endurance-focused stations (Faigenbaum et al., 2007). For example, a circuit might consist of a squat-to-press, followed by jump lunges, a core exercise such as hanging leg raises, and a plyometric drill, like box jumps. This combination simultaneously enhances muscular power, cardiovascular endurance, and core strength, presenting a comprehensive and efficient workout methodology (Gäbler et al., 2018).

The benefits of a structured plyometric program showcase remarkable enhancements in core strength and balance for athletes and emphasise its positive influence on trunk stability (Torbatinezhad et al., 2019). Similarly, circuit training, which includes bodyweight and resistance exercises, significantly boosts core endurance and dynamic stability in recreationally active adults (Son et al., 2023). Nevertheless, we lack thorough comparative studies exploring these training methods under controlled conditions, specifically focusing on core outcomes. This study is set to fill that gap by

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rigorously evaluating and comparing the effectiveness of plyometric and circuit training in elevating core conditioning.

This study aims to evaluate and compare the effectiveness of circuit and plyometric training in enhancing core strength and abdominal endurance among physically active individuals. The research assesses explicitly how circuit training, which consists of a sequence of resistance and bodyweight exercises targeting the core, affects muscular endurance and trunk stability. Concurrently, it examines the effects of plyometric training, characterised by explosive, high-velocity movements, on dynamic core performance and neuromuscular efficiency. The study seeks to determine which training modality yields superior results by implementing a 12-week intervention for both training groups and measuring key performance indicators such as sit-up endurance and plank hold time.

Methodology

Research Design

The primary objective of this study was to determine whether plyometric or circuit training is more effective in enhancing core strength and endurance compared to a control group. This investigation utilised an experimental research design featuring a pre-test and post-test control group model to evaluate the impact of both training methods on core conditioning. The independent variable was the type of training, categorised into Plyometric Training and Circuit Training. The dependent variables included abdominal endurance, assessed through sit-up performance, and core strength, which were evaluated using the plank test. The pre-test scores served as covariates for the analysis.

Participants

Sixty male participants aged between 15 and 17 were recruited for the study. The researchers used random sampling as the sampling technique. All participants were healthy individuals with no prior history of core muscle injuries. They regularly engaged in physical activities but had not participated in structured core-specific training. The researchers conducted an initial screening using questionnaires, enrollment forms, and preliminary interviews to ensure the participants met the inclusion and exclusion criteria.

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They also requested supporting documents for validation and verification, such as exercise history, medical records, and parental consent.

The participants were randomly assigned to three groups, each consisting of 20 individuals: the Plyometric Training Group (PTG), the Circuit Training Group (CTG), and the Control Group (CG). During the research implementation, all participants maintained a 95% attendance rate; none were excluded from the training program. All 60 participants were fully involved in the research activities, with an average age of 15.75 years (± 0.69), height of 172.21 cm (± 5.02), weight of 84.79 kg (± 6.17), and a Body Mass Index (BMI) of 28.79 (± 1.58). All participants came from the same geographical area.

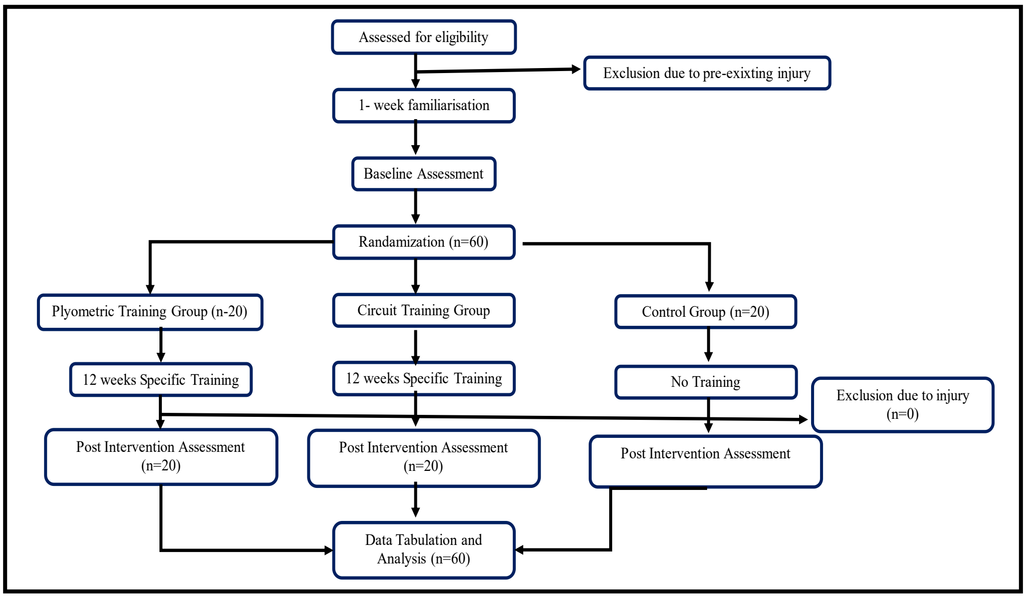

Figure 1. Flow diagram of study group randomisation

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Intervention

Table I. Plyometric training schedule for 12 weeks

Weeks	Exercises	Set/Repetition	Intensity	Rest
1 – 4	1. Jumping Lunges with Torso Twist 2. Medicine Ball Overhead Throws 3. Explosive Push-Ups 4. 20 m bounding	2 x 10 2 x 10 2 x 10 2 x 5	65 to 75 %	1Min / 4Min 1Min / 4 Min 1Min / 4 Min 1Min / 4 Min
5 – 8	1. Hurdle jump 50 cm 2. Drop jump 20 cm 3. Plyometric V-Ups 4. Lateral Bounding with Reach	2 x 10 2 x 10 2 x 10 2 x 5	75 to 85 %	1Min / 5 Min 1Min / 5 Min 1Min / 5 Min 1Min / 5 Min
9 – 12	1. Drop to hurdle jump (20 cm to 50 cm) 2. Plyometric V-Ups 3. Explosive Push-Ups 4. Russian Twists with Medicine Ball	2 x 10 2 x 10 2 x 10 2 x 10	85 to 95 %	2Min / 5 Min 2Min / 5 Min 2Min / 5 Min 2Min / 5 Min

Table II. Circuit training group training program for 12 weeks

Weeks	Exercises	Set/Repetition	Intensity	Rest
1– 4	1. Leg Raises 2. Star jump 3. Push-ups 4. Back Extensions	2x45 Sec 2x45 Sec 2x45 Sec 2x45 Sec	65 to 75 %	1Min / 4Min 1Min / 4 Min 1Min / 4 Min 1Min / 4 Min
5– 8	1. Toe Touch Crunches 2. Bird-Dog 3. Stability Ball Rollouts 4. Bicycle Crunches	2x45 Sec 2x45 Sec 2x45 Sec 2x45 Sec	75 to 85 %	1Min / 5 Min 1Min / 5 Min 1Min / 5 Min 1Min / 5 Min
9– 12	1.Leg Raises 2.Stability Ball Rollouts 3.Toe Touch Crunches 4.Back Extensions	2x45 Sec 2x45 Sec 2x45 Sec 2x45 Sec	85 to 95 %	2Min / 5 Min 2Min / 5 Min 2Min / 5 Min 2Min / 5 Min

Table I. and **Table II**. show that the training intervention lasted 12 weeks, with sessions held three times a week, each lasting between 45 and 60 minutes. The Plyometric Training Group (PTG) performed exercises to strengthen core muscles, while the Circuit

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Training Group (CTG) followed a series of core-focused circuit exercises based on sports training principles. The Control Group (CG) did not participate in any specific core training but continued with their regular physical activities. Pre-tests were conducted before the intervention to establish baseline abdominal endurance and core strength measurements. Following a 12-week training period, post-tests were performed to evaluate progress. Abdominal endurance was assessed using the sit-up test, which recorded the maximum number of sit-ups completed in one minute. Core strength was evaluated through the plank test, measuring how long a participant could maintain a standard plank position.

Data analysis

Statistical analysis was performed using Analysis of Covariance (ANCOVA) to compare post-test scores while controlling for variations in pre-test scores. The significant level was set at a 0.05 confidence level ($p<0.05$), and the post-hoc paired mean difference was computed using Scheffe's post-hoc test. The data were compiled and analysed using the statistical package for social science (SPSS) for Windows computer software.

Potential ethical issues

Ethical considerations were rigorously maintained throughout the study. Participants provided informed consent, and parental consent was obtained for minors where applicable. The research conformed to ethical guidelines for human research, ensuring participant safety by implementing appropriate warm-up and cool-down protocols. The University of Alagappa granted ethical approval, and the study adhered to ethical standards outlined in the 2013 Declaration of Helsinki regulation.

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Results

Table III. Mean (±SD) values of Anthropometric characteristics for the Plyometric training, Circuit training and Control groups

Variables	Group	Pre-test	Post-test	% Change
Body mass (kg)	PTG	83.26±5.17	79.61±4.19	-4.38
	CTG	86.17±6.28	83.51±6.17	-3.08
	CG	84.94±6.94	85.13±6.05	+0.22
Height (cm)	PTG	170.16±5.13	170.16±5.13	0.00
	CTG	172.94±4.76	172.94±4.76	0.00
	CG	173.54±5.18	173.54±5.18	0.00
BMI (kgm-2)	PTG	28.86±1.61	27.33±1.51	-5.31
	CTG	29.12±1.19	28.22±1.43	-3.09
	CG	28.38±1.87	28.44±1.81	+0.21
% Body fat (%)	PTG	38.54±0.52	35.19±0.46	-8.69
	CTG	38.91±0.49	36.01±0.53	-7.45
	CG	38.67±0.47	38.75±0.43	+0.21

Table III shows the study examined the anthropometric characteristics of three groups: the Plyometric Training Group (PTG), the Circuit Training Group (CTG), and the Control Group (CG). Before and after the intervention, measurements were taken for body mass, height, BMI, and body fat percentage.

The results indicated significant changes in body composition among the PTG and CTG, while the CG showed minimal variation. The PTG experienced the most significant reduction in body mass, decreasing from 83.26 ± 5.17 kg to 79.61 ± 4.19 kg, representing a 4.38% decrease. Similarly, the CTG declined from 86.17 ± 6.28 kg to 83.51 ± 6.17 kg, marking a 3.08% reduction. In contrast, the CG slightly increased from 84.94 ± 6.94 kg to 85.13 ± 6.05 kg (+0.22%), indicating no significant weight loss effect without intervention. Height remained unchanged across all groups, as expected over the study's duration. However, BMI showed notable reductions in both the PTG and CTG. The PTG demonstrated the most significant improvement, with a decrease in BMI from 28.86 ± 1.61 to 27.33 ± 1.51 (-5.31%), followed by the CTG, which decreased from 29.12 ± 1.19 to 28.22 ± 1.43 (-3.09%). Conversely, the CG experienced a slight increase in BMI, rising from 28.38 ± 1.87 to 28.44 ± 1.81 (+0.21%), further reinforcing the effectiveness of the training interventions. Body fat percentage exhibited the most dramatic changes among

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all variables. The PTG showed the most significant reduction, dropping from 38.54 ± 0.52% to 35.19 ± 0.46% (-8.69%). The CTG also experienced a decline, reducing from 38.91 ± 0.49% to 36.01 ± 0.53% (-7.45%). In contrast, the CG saw a slight increase in body fat percentage, from 38.67 ± 0.47% to 38.75 ± 0.43% (+0.08%), indicating that without a structured training program, body fat levels either remained unchanged or increased slightly.

Abdominal Endurance

The analysis of abdominal endurance across different training groups provides a clear insight into the effectiveness of Plyometric Training (PTG) and Circuit Training (CTG) compared to a Control Group (CG)

Table IV. Analysis of covariance for abdominal endurance on Plyometric training, circuit training, and control group students

Test		PTG	CTG	CG	SV	SS	Df	MS	F	P
Pre-test	Mean ±SD	24.35 ±3.18	23.25 ±4.28	23.05 ±3.77	Between	18.53	2	9.267	0.652	0.525
					Within	810.23	57	14.21		
Post-test	Mean ±SD	38.65 ±2.54	35.3 ±4.85	24.05 ±4.37	Between	2339.63	2	1169.81	71.518	0.000
					Within	932.63	57	16.35		
Ad. post-test	Mean	39	36	24	Between	2520	2	1260	58.36	0.000
					Within	1209.04	56	21.59		

Table IV. shows that before the training intervention, the mean values for the Plyometric Training Group (PTG) were 24.35 ± 3.18, the Circuit Training Group (CTG) were 23.25 ± 4.28, and the Control Group (CG) were 23.05 ± 3.77. These values were relatively close, indicating that all three groups started with a similar baseline level of abdominal endurance. The statistical analysis yielded an F-value of 0.652 and a p-value of 0.525, indicating no statistically significant differences among the groups before the training. This suggests that any improvements in the post-test results can be attributed to the training interventions rather than pre-existing differences. Following the intervention, there was a notable improvement in abdominal endurance for the PTG and CTG groups, while the CG showed little to no progress. The PTG group experienced the highest improvement, with a mean value of 38.65 ± 2.54, followed by the CTG group at 35.3 ±

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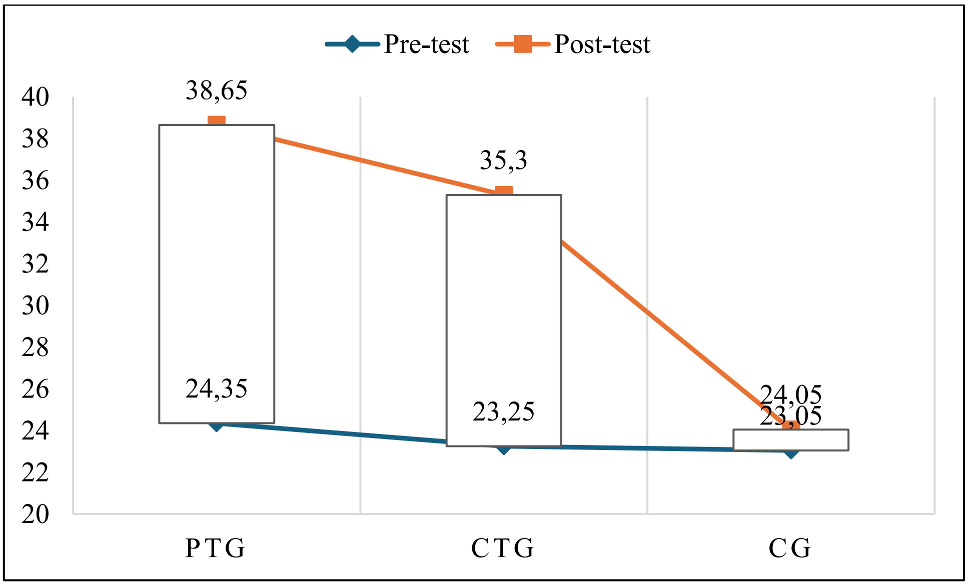
4.85. In contrast, the CG had a mean value of only 24.05 ± 4.37, indicating minimal change. The statistical analysis yielded an F-value of 71.518 and a p-value of 0.000, revealing a highly significant difference between the groups. This confirms that plyometric and circuit training had a statistically significant impact on abdominal endurance, whereas the control group did not undergo structured training and showed negligible improvement.



Graph I. Abdominal endurance on Plyometric training, circuit training, and control group students

An adjusted post-test was conducted to account for baseline differences and refine the results further. The mean values were still high for the PTG (39) and CTG (36) compared to the CG (24). The F-value of 58.36 and p-value of 0.000 further validated that the differences between the groups were statistically significant. The slightly greater improvement in the PTG group suggests that plyometric training may be more effective in enhancing abdominal endurance than circuit training. The results demonstrate that both plyometric and circuit training effectively improve abdominal endurance, with plyometric training showing slightly more significant gains. This could be attributed to plyometric exercises' explosive, high-intensity nature, which may lead to better neuromuscular adaptations. The circuit training group also exhibited significant improvements, likely due to the combination of strength and endurance exercises targeting the core muscles. On the other hand, the minimal progress of the control group underscores the importance

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of structured training programs in enhancing fitness components such as abdominal endurance.

Table V. Scheffe's post hoc paired means comparisons on the abdominal endurance of experimental and control groups.

Mean value			Mean Difference	LS
Plyometric Training	**Circuit Training**	**Control Group**		
39	36		03	0.05
	36	24	12	0.05
39		24	15	0.05

Note: significant at 0.05 level
Scheffe's C.I value = 2.65

Table V. The results of Scheffé's post hoc paired means comparisons on the abdominal endurance of the experimental and control groups revealed significant differences among the groups. The mean values for the adjusted post-test scores were 39 for the Plyometric Training Group, 36 for the Circuit Training Group, and 24 for the Control Group. Using the values from the ANOVA table, Scheffé's confidence interval (C.I.) was calculated to be 2.65. When comparing the group means, the differences observed were 3 points between the Plyometric and Circuit Training groups, 12 points between the Circuit and Control groups, and 15 points between the Plyometric and Control groups. All these differences exceeded Scheffé's C.I. of 2.65, indicating that they were statistically significant at the 0.05 level. As a result, both plyometric and circuit training significantly improved abdominal endurance compared to the control group, with plyometric training demonstrating a significantly more significant improvement than circuit training.

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Core Muscle Strength

Table VI. Analysis of covariance for core muscle strength on Plyometric training, circuit training, and control group students

Test		PTG	CTG	CG	SV	SS	Df	MS	F	P
Pre-test	Mean ±SD	42.74 ±4.18	44.67 ±3.78	44.73 ±4.75	Between	51.25	2	25.63	1.41	0.251
					Within	1032.15	57	18.11		
Post-test	Mean ±SD	56 ±4.57	53.25 ±3.51	45.01 ±4.36	Between	1310.83	2	655.41	37.66	0.000
					Within	992.07	57	17.41		
Ad. post-test	Mean	55	54	46	Between	973.2	2	486.6	27.2	0.000
					Within	1000	56	17.86		

Table VII shows that the findings from our study reveal a remarkable and positive effect of both plyometric training (PTG) and circuit training (CTG) on core muscle strength when compared to the control group (CG). Initially, during the pre-test phase, the average core strength scores were similar across all groups: PTG at 42.74 ± 4.18, CTG at 44.67 ± 3.78, and CG at 44.73 ± 4.75, showing no significant differences ($F = 1.41$, $p = 0.251$). This indicated that everyone began with comparable core strength levels. After completing the training programs, we observed tremendous improvements in core muscle strength for both experimental groups! The PTG group excelled with a mean increase to 56 ± 4.57, while the CTG followed closely behind at 53.25 ± 3.51. In contrast, the CG only slightly improved to 45.01 ± 4.36. The analysis of variance (ANOVA) revealed a significant difference among the groups ($F = 37.66$, $p < 0.001$), strongly supporting the effectiveness of both plyometric and circuit training in enhancing core strength.

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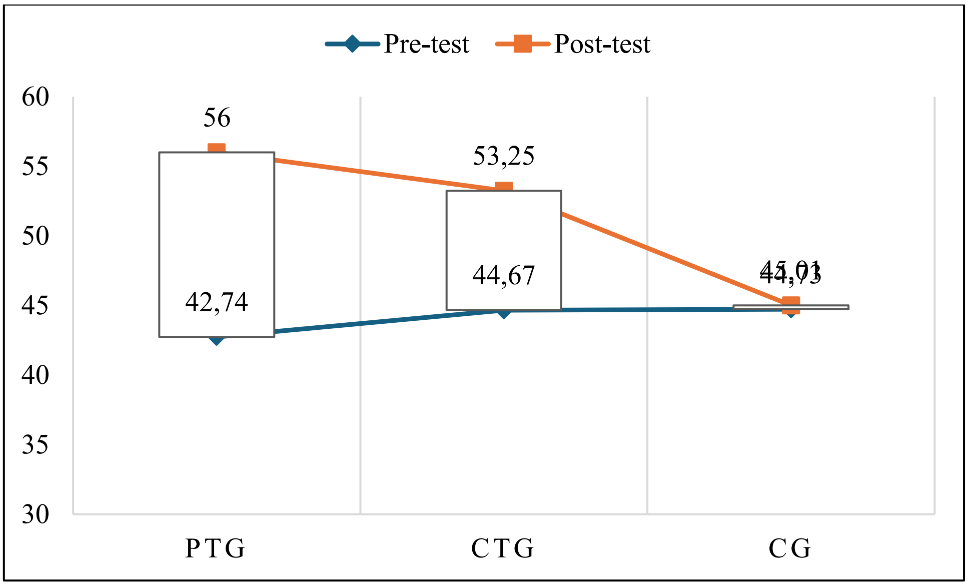

Graph II. Core muscle strength on Plyometric training, circuit training, and control group students

Moreover, after adjusting for initial differences, the post-test scores further highlighted the success of the training programs: PTG averaged 55, CTG 54, and CG 46. The statistical significance remained robust (F = 27.2, p = 0.000), confirming that the progress seen in the experimental groups directly resulted from the specific training methods rather than chance. Interestingly, plyometric training slightly outshone circuit training regarding core muscle strength gains. This can likely be credited to the dynamic, high-intensity movements typical of plyometric exercises, which improve neuromuscular coordination, muscle activation, and core stability. While circuit training is highly effective and practical, it may not engage the core as intensely as plyometric workouts.

Table VII. Scheffe's post hoc paired means comparisons on the core muscle strength of experimental and control groups

Mean value			Mean Difference	LS
Plyometric Training	**Circuit Training**	**Control Group**		
55	54		01	0.05
	54	46	08	0.05
55		46	09	0.05

Note: significant at 0.05 level
Scheffe's C.I value = 2.42

Table VIIII. Scheffé's post hoc paired means comparisons revealed varying significance levels in core muscle strength among the experimental and control groups. The adjusted post-test mean values were 55 for the Plyometric Training Group, 54 for the

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Circuit Training Group, and 46 for the Control Group. The confidence interval (C.I.) calculated using Scheffé's method was 2.42. The difference between the Plyometric and Circuit Training groups was only 1, less than the critical interval, indicating that this difference was not statistically significant. However, the differences between the experimental and Control groups were significant: Plyometric Training compared to Control showed a difference of 9, while Circuit Training compared to Control showed a difference of 8. These differences exceeded the C.I. and were statistically significant at the 0.05 level. These results suggest that Plyometric and Circuit Training significantly improved core muscle strength compared to the Control group, while the difference between the two experimental groups was insignificant.

Discussion

The results from this study shine a light on the remarkable anatomical benefits that plyometric and circuit training can have on abdominal endurance and core muscle strength. Initially, all three groups demonstrated similar baseline levels of abdominal endurance, with average values showing no significant differences (PTG at 24.35 ± 3.18, CTG at 23.25 ± 4.28, and CG at 23.05 ± 3.77). However, the excitement begins after the 12-week training program, where we see both the plyometric training group (PTG) and the circuit training group (CTG) make impressive strides!

The results reveal that the PTG group achieved outstanding growth, reaching an impressive average of 38.65 ± 2.54, while the CTG group followed closely at 35.3 ± 4.85. In stark contrast, the control group (CG) showed a modest increase, landing at a post-test mean of 24.05 ± 4.37. The remarkable F-value of 71.518 ($p = 0.000$) highlights the effectiveness of these training regimens, particularly showcasing the exceptional progress made by both the PTG and CTG. Engaging in structured core training programs is essential for enhancing abdominal endurance with efficient plyometric training.

The explosive, high-energy movements characterising plyometric exercises will likely trigger more excellent neuromuscular adaptations, enhancing endurance and muscle activation (Furrer et al., 2023; Myer et al., 2006; Paavolainen et al., 1999). Similar neurophysiological effects have been observed in different contexts, such as during active breaks in schoolchildren, where such activities significantly improve neuromuscular

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responses and cognitive functions (Valero-valenzuela, et al., 2025) Circuit training, although slightly less effective than plyometric training in this study, still provided significant advantages by combining strength and endurance exercises, effectively promoting core engagement and muscular endurance (Strelnikowa & Polevoy, 2018; Zquierdo, 2013). The minimal progress observed in the control group underscores the critical need for targeted training programs to develop core endurance fully.

In terms of core muscle strength, the improvements followed a similar encouraging trend. At the beginning of the study, participants showed average core strength scores that indicated no significant disparities among the groups: PTG at 42.74 ± 4.18, CTG at 44.67 ± 3.78, and CG at 44.73 ± 4.75. However, after the intervention, both experimental groups demonstrated significant improvements, with the PTG leading the way at an impressive 56 ± 4.57, closely followed by CTG at 53.25 ± 3.51. Conversely, the CG showed a slight enhancement to 45.01 ± 4.36. The ANOVA results revealed a substantial difference between the groups ($F = 37.66$, $p < 0.001$), reinforcing the transformative impact of structured core training. Post-test values further emphasise these findings, with PTG achieving an impressive adjusted mean of 55 and CTG at 54, significantly outpacing the control group's score of 46. The statistical significance remained robust ($F = 27.2$, $p = 0.000$), underscoring the remarkable advancements made by the experimental groups. The superior improvements in the plyometric training group suggest that the nature of these exercises, with their explosive and high-intensity characteristics, is vital for developing neuromuscular efficiency, muscle activation, and core stability (Chu & Myer, 2013; LaChance, 1995).

From an anatomical standpoint, the enhancements in abdominal endurance and core strength stem from the specific physiological adaptations of these dynamic training modalities (Huxel Bliven & Anderson, 2013; Mohanta et al.., 2019). Plyometric exercises prompt rapid and forceful muscle contractions, stimulating the neuromuscular system and bolstering the activation of fast-twitch muscle fibers crucial in generating explosive movements (Ma et al., 2024). When targeted correctly, these exercises significantly increase core strength and endurance (Cabrejas et al., 2023). Moreover, engaging key muscle groups such as the rectus abdominis, oblique, and transverse abdominis during plyometric routines strengthens these vital muscles, enhancing durability and stability

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(Hansen & Kennelly, 2017). Plyometric training promotes proprioception and coordination, improving core control and muscular efficiency (Laskowski et al., 2000; Riva et al., 2016). This effectiveness is further supported by prior research (Booth & Orr, 2016; Branet et al., 2020) highlighting the advantages of plyometric drills in enhancing neuromuscular efficiency, a fundamental aspect of core stabilisation and force production.

Although slightly less impactful than plyometric training, Circuit training enhances core endurance and strength (Deng et al., 2023). This training combines strength and endurance exercises performed sequentially with minimal rest, fostering muscular and cardiovascular improvements (Ketelhut & Ketelhut, 2020). By incorporating core-focused exercises into the circuit, participants ensure continuous engagement of abdominal and stabilising muscles, which fosters significant gains in muscular endurance and strength over time(Wang & Zhang, 2016).

The study had several limitations that could impact the interpretation and generalizability of its findings. Firstly, it involved only 60 male adolescents divided into three groups, which limits reliability and broader applicability. The short intervention period of 12 weeks may not adequately capture long-term effects. Also, the study did not control for dietary habits, sleep patterns, or physical activity levels outside the intervention, which could influence outcomes. Psychological factors like motivation and adherence were also not assessed. Conducted in a single region and educational setting, the findings may not apply to other contexts. Also, while standard field tests were used for performance measurement, they may lack the precision offered by advanced laboratory assessments.

Conclusion

In conclusion, this study reveals that plyometric and circuit training are effective methodologies for enhancing core strength and endurance. Integrating these approaches into fitness regimens can significantly improve individuals' overall fitness, health, and physical performance. Engaging with these training modalities promises increased muscular strength and cultivates a sense of accomplishment and empowerment throughout the fitness journey.

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