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ORIGINAL ARTICLE

The effect of bodyweight circuit training on flexibility and strength endurance in male tennis players

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Flexibility and strength endurance are essential components of tennis performance. This study aims to evaluate the effectiveness of bodyweight circuit training (BCT) in enhancing flexibility and strength endurance in male university tennis players.

Material and Methods This study employed a true experimental design with a pretest-posttest control group. A total of 30 male tennis players, aged 19–23 years, were recruited from a university. Participants were randomly assigned to either a control group (CTr, n=15) or a training group (TRg, n=15) based on predefined criteria. The training group underwent a bodyweight circuit training (BCT) program three times per week for four weeks. Flexibility was assessed using the Sit and Reach Test. Strength endurance was evaluated through three tests: upper body strength endurance with the 60-second Push-Up Test, abdominal strength endurance with the 60-second Sit-Up Test, and back strength endurance with the 60-second Back Extension Test. Measurements were taken at baseline (pre) and after four weeks (post). Data analysis was conducted using paired and independent sample t-tests, with a significance level set at 5%.

Results Significant improvements in flexibility, upper body strength endurance, abdominal strength endurance, and back strength endurance were observed in the training group (TRg) between pre- and post-intervention ($p \leqslant 0.05$). In contrast, no significant changes were found in the control group (CTr) ($p \geqslant 0.05$). At baseline, no significant differences were detected between the TRg and CTr groups ($p \geqslant 0.05$). However, post-intervention analysis revealed significantly greater improvements in the TRg group compared to the CTr group ($p \leqslant 0.05$).

Conclusions BCT implementation in training programs may contribute to improved physical performance. These findings suggest that BCT could be integrated into structured training regimens to support athletic development.

Keywords: bodyweight circuit training, flexibility, strength endurance, tennis player

Introduction

Flexibility and strength endurance are essential components of tennis performance [1]. As a sport that involves rapid movements, precise shots, and high mobility, tennis requires stable muscle strength and optimal flexibility to enhance movement efficiency, reduce injury risk, and sustain endurance throughout matches [2]. Good flexibility allows players to reach difficult shots more easily, while high strength endurance supports consistent performance, particularly during extended rallies that demand greater physical resilience [3]. Limited flexibility can restrict movement and negatively impact performance, especially in strokes requiring maximum reach [4, 5]. Therefore, training programs that incorporate flexibility and strength endurance development are essential for tennis athletes.

Various training methods have been implemented to enhance the physical capabilities of tennis players, including conventional exercises such as weight training and plyometrics, as well as functional training methods [3, 6]. Functional training aims to improve strength, endurance, and body stability by incorporating movement patterns that mimic sports-specific activities [7]. These exercises focus on core muscle strengthening, joint stabilization, and explosive strength development, all essential for optimal tennis performance [7]. However, while functional training is generally effective in improving several physical attributes,

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its impact on flexibility and muscle endurance remains a subject of debate among coaches and researchers [3]. This limitation is believed to result from training approaches that primarily emphasize muscle strengthening within a restricted range of motion, thereby failing to adequately develop muscle elasticity and joint mobility.

Bodyweight Circuit Training (BCT) was developed as an extension of functional training to overcome its limitations by incorporating broader and more dynamic movements. Inspired by natural animal movements such as crawling, jumping, and lateral motions, BCT integrates functional training elements, including push-ups, walking lunges with torso twists, bicycle crunches, back extensions, lateral squats, and supinated Australian pull-ups [8]. These movement patterns not only enhance strength, endurance, and stability but also improve dynamic flexibility and agility. For example, walking lunges with torso twists increase hip and spinal flexibility [9, 10], while bicycle crunches strengthen core muscles through rotational patterns relevant to forehand and backhand strokes [11, 12]. This combination makes BCT a comprehensive approach to developing flexibility, strength, and agility, aligning with the physical demands of tennis athletes.

The effectiveness of BCT in improving flexibility and strength endurance lies in its design, which emphasizes multidimensional and function-based movements. Exercises such as crawling and jumping engage a full range of motion, directly stretching major muscles while enhancing the elasticity of connective tissues [13, 14]. The combination of dynamic and isometric movements provides optimal stimulation to strengthen the core, back, and other muscle groups [15, 16]. Additionally, the circuit training format of BCT incorporates high-intensity exercises, which not only enhance muscular endurance but also improve neuromuscular coordination, enabling more efficient movement and greater resistance to fatigue [17]. By integrating movement patterns that resemble natural body mechanics, BCT supports flexibility development and optimizes the strength required for tennis performance [2, 8, 18]. This approach makes BCT valuable not only for improving athletic performance but also for reducing the risk of injuries associated with flexibility limitations and repetitive motions common in tennis.

Although BCT has been applied in various sports, such as gymnastics and martial arts, research on its effectiveness for tennis athletes remains limited. Most previous studies have focused on conventional training methods or functional training without examining more comprehensive approaches that simultaneously enhance flexibility and muscle endurance [6]. Additionally, the optimal training duration for maximizing BCT benefits has yet to be determined.

Therefore, this study aims to evaluate the effectiveness of a four-week BCT program in improving flexibility and strength endurance in male university tennis players.

Materials and Methods

Participants

This study employed a true experimental design with a pretest-posttest control group. A total of 30 male tennis players aged 19–23 years, with a normal body mass index (BMI) (19–24 kg/m^2), normal blood pressure, resting heart rate, and oxygen saturation, were recruited from Universitas Negeri Surabaya (UNESA). Participants who met the eligibility criteria were randomly assigned to either the control group (CTr, n=15) or the training group (TRg, n=15). Before participation, all players received verbal and written explanations about the study. Informed consent was obtained through signed consent forms prior to their involvement.

Research Design

Bodyweight Circuit Training Protocol

The Bodyweight Circuit Training (BCT) protocol was implemented and supervised by personal trainers from the Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya. Trainers ensured the proper execution of all movements throughout the program. The BCT program included exercises such as push-ups, walking lunges with torso twists, bicycle crunches, back extensions, lateral squats, and supinated Australian pull-ups. Each session consisted of 4–6 sets of 12–15 repetitions and was conducted three times per week for four weeks. Training sessions took place outdoors at the UNESA Tennis Courts every morning between 6:00 and 8:00 AM.

Data Collection

Flexibility and strength endurance were assessed at baseline (pre) and after four weeks (post) in both groups. Flexibility was measured using the Sit and Reach Test (cm). Upper body strength endurance was evaluated using the 60-second Push-Up Test (repetitions), abdominal strength endurance using the 60-second Sit-Up Test (repetitions), and back strength endurance using the 60-second Back Extension Test (repetitions) [19].

Statistical Analysis

Statistical analysis was conducted using SPSS Statistics for Windows, Version 21.0. Data normality was assessed using the Shapiro-Wilk test. Paired sample t-tests were used to compare flexibility and strength endurance within each group at baseline (pre) and after four weeks (post). Independent sample t-tests were applied to compare differences between the control and training groups. Effect sizes were calculated using Cohen's d and categorized as small (d = 0.2), medium (d = 0.5), and large (d ⩾ 0.8) [20]. Statistical significance was set at p ⩽ 0.05 for all analyses.

Results

The general characteristics of the participants are presented in Table 1. No significant differences were found between the control (CTr) and training (TRg) groups in age, body height, body mass index, blood pressure, or resting heart rate (all p ⩾ 0.05). The flexibility and strength endurance results at baseline (pre) and after four weeks (post) for each group are shown in Figure 1.

Based on the trend shown in Figure 1, significant improvements in flexibility, upper body strength endurance, abdominal strength endurance, and back strength endurance were observed in the training group (TRg) between baseline (pre) and post-intervention (all p ⩽ 0.05). In contrast, no significant changes were found in the control group (CTr) (all p ⩾ 0.05). To compare differences between groups, an independent sample t-test analysis was performed, and the results are presented in Table 2.

At baseline, no significant differences were observed between the TRg and CTr groups in flexibility, upper body strength endurance,

Table 1. General Characteristics of Participants

Parameters	CTr (n=15)	TRg (n=15)	p-value
Age, yrs	20.47 ± 0.99	20.60 ± 1.12	0.733
Body height, m	1.66 ± 0.04	1.67 ± 0.04	0.249
Body weight, kg	58.20 ± 4.01	59.47 ± 5.06	0.453
Body mass index, kg/m^2	21.24 ± 0.89	21.28 ± 1.05	0.920
Systolic blood pressure, mmHg	117.33 ± 7.04	115.33 ± 5.17	0.383
Diastolic blood pressure, mmHg	78.00 ± 6.76	78.67 ± 5.16	0.764
Resting heart rate, bpm	69.60 ± 4.97	68.80 ± 11.23	0.804

CTr: Control group; TRg: Training group. p-values were obtained using independent sample t-tests. Data are presented as mean ± standard deviation (SD).

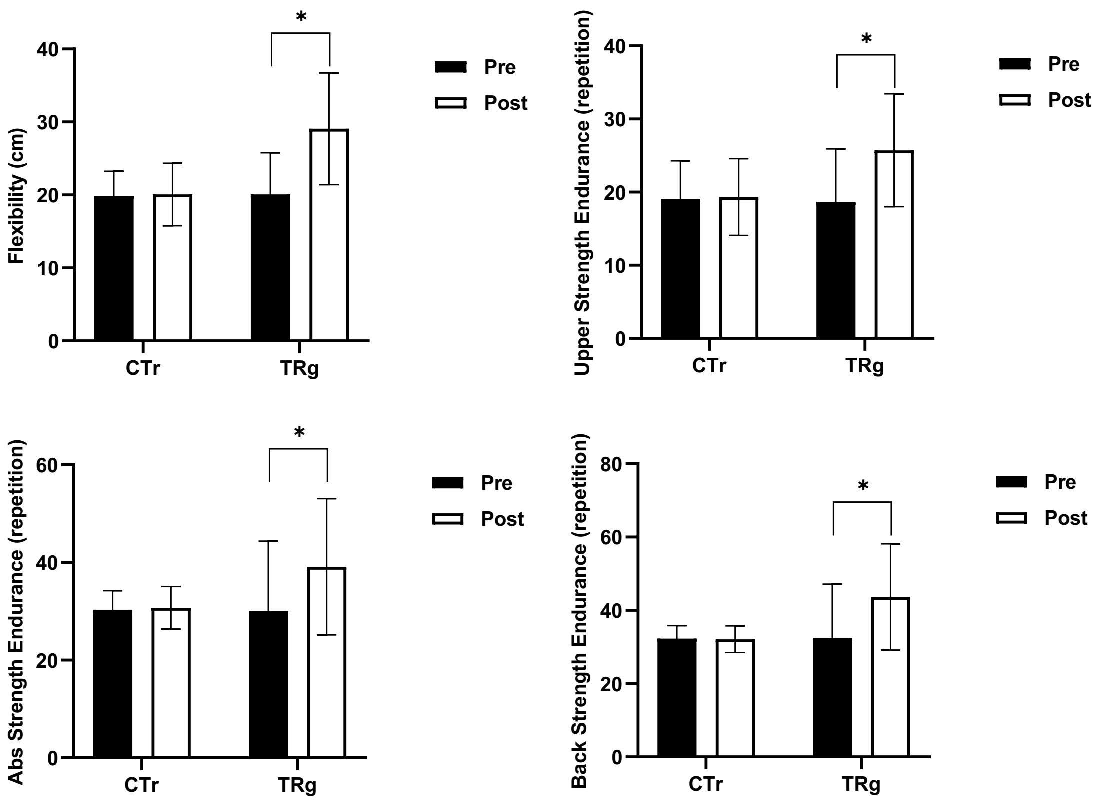

Figure 1. Assessment of flexibility (cm), upper strength endurance (repetition), abs strength endurance (repetition), and back strength endurance (repetition) baseline (pre) and 4 weeks (post) in each group. *significant at pre in TRg (p ⩽ 0.05). p-value was obtained from the results of paired sample t-test analysis. CTr: Control group; TRg: Training group.

Table 2. Assessment of Flexibility and Strength Endurance Between Groups

Parameters	CTr (n=15)	TRg (n=15)	95% CI	p-value	ES
Flexibility (cm)					
Pre	19.87 ± 3.39	20.07 ± 5.70	-3.75 to 3.35	0.908	0.042
Post	20.06 ± 4.27	29.07 ± 7.66*	-13.69 to -4.31	0.001	1.452
Delta	0.20 ± 1.37	9.00 ± 4.58*	-11.41 to -6.19	0.000	2.601
Upper Strength Endurance (repetitions)					
Pre	19.07 ± 5.23	18.67 ± 7.26	-4.35 to 5.15	0.864	0.063
Post	19.33 ± 5.26	25.73 ± 7.71*	-11.36 to -1.44	0.013	0.971
Delta	0.27 ± 0.96	7.07 ± 2.92*	-8.47 to -5.13	0.000	3.133
Abdominal Strength Endurance (repetitions)					
Pre	30.33 ± 3.87	30.07 ± 14.29	-7.84 to 8.37	0.945	0.025
Post	30.73 ± 4.35	39.13 ± 13.96*	-16.38 to -0.42	0.034	0.812
Delta	0.40 ± 1.18	9.07 ± 1.03*	-9.49 to -7.84	0.000	7.803
Back Strength Endurance (repetitions)					
Pre	32.27 ± 3.57	32.53 ± 14.66	-8.54 to 8.01	0.946	0.024
Post	32.13 ± 3.66	43.67 ± 14.51*	-19.73 to -3.34	0.009	1.091
Delta	-0.13 ± 1.51	11.13 ± 6.93*	-15.16 to -7.37	0.000	2.247

CI: Confidence Interval; ES: Effect Size; CTr: Control group; TRg: Training group. *Significant at CTr ($p \leqslant 0.05$). Data are presented as mean ± standard deviation (SD).

abdominal strength endurance, or back strength endurance (all $p \geqslant 0.05$). However, post-intervention and delta analyses revealed significantly greater improvements in the TRg group compared to the CTr group (all $p \leqslant 0.05$).

Discussion

The findings of this study demonstrate that a four-week Bodyweight Circuit Training (BCT) program significantly improved flexibility by 49.29%, upper body strength endurance by 44.27%, abdominal strength endurance by 37.64%, and back strength endurance by 40.21%. These improvements highlight the effectiveness of BCT as a comprehensive training method that meets the physical demands of tennis players by integrating flexibility and muscular endurance to support optimal on-court performance. Enhanced flexibility allows athletes to reach difficult shots more efficiently, while greater strength endurance contributes to body stability and stroke consistency during long matches or intense rallies [2, 21]. The combination of these two elements is essential for improving movement efficiency and reducing the risk of injuries caused by repetitive or sudden movements [4, 5]. These findings emphasize the importance of training programs that simultaneously enhance flexibility and muscular endurance for tennis players.

The observed results can be attributed to the design of BCT exercises, which include push-ups, walking lunges with torso twists, bicycle crunches, back extensions, lateral squats, and supinated Australian pull-ups. Each movement plays a specific role in enhancing flexibility and strength endurance. For example, walking lunges with torso twists improve hip and spinal mobility, promoting muscle elasticity and dynamic flexibility [10]. Bicycle crunches not only strengthen the core muscles but also incorporate rotational patterns relevant to forehand and backhand strokes [12]. Additionally, exercises such as push-ups and supinated Australian pull-ups target upper body strength, which is essential for supporting overhead movements in tennis [22, 23, 24]. The back extension exercise strengthens the lower back, playing a crucial role in maintaining posture during explosive strokes [25, 26]. Thus, the combination of these movements in BCT provides targeted stimulation to major muscle groups, making it a more sport-specific and relevant training method compared to conventional or other functional training approaches.

The effectiveness of BCT in improving flexibility and muscular endurance can also be explained by its underlying physiological mechanisms. Full-range-of-motion exercises, such as walking lunges and lateral squats, enhance connective tissue elasticity and joint mobility [27, 28]. Additionally, the high intensity of BCT promotes metabolic adaptations in muscles, increasing energy efficiency and reducing fatigue during physical activity [17]. Dynamic movements, such as walking lunges, combined with isometric exercises, such as push-ups, strengthen neuromuscular coordination, allowing the body to respond more rapidly and efficiently to changing match conditions. This movement-based approach positions BCT as a training method that not only enhances physical performance but also improves movement efficiency and postural stability, both of which are essential in tennis.

These findings are consistent with previous research. This study supports the results of Polsgrove et al., who reported that full-range-of-motion exercises effectively enhance lower body flexibility [10]. Similarly, the findings align with James et al., who demonstrated that combining dynamic and isometric movements significantly improves muscular endurance compared to traditional training methods [8]. A key contribution of this study is the application of BCT specifically to address the physical demands of tennis players, who require dynamic flexibility, core strength, and high muscular endurance.

The practical relevance of these findings extends to both tennis coaches and athletes. Optimal flexibility allows players to expand their range of motion and reduce the risk of injuries associated with repetitive or sudden movements. Improved strength endurance helps maintain stroke intensity and body stability during long matches. Beyond tennis, BCT has potential applications in other sports, such as badminton, squash, and basketball, which require a combination of flexibility, endurance, and muscular strength. Due to its simple yet effective structure, BCT can be incorporated as a primary or supplementary program within functional training regimens to enhance overall physical performance.

However, this study has several limitations that should be acknowledged. The relatively short training duration (four weeks) may not have been sufficient to assess the long-term effects of BCT on athletes' physical performance. Additionally, the study was limited to tennis players from a single institution, which may restrict the generalizability of the findings to a broader population or other sports. Responses to BCT may also vary among athletes with different skill levels or prior training experience. Furthermore, key physical parameters such as agility, explosive strength, and injury risk were not evaluated, despite their relevance to optimal performance in competitive sports.

Based on these limitations, future research should include a more diverse population, incorporating athletes from different sports and skill levels to improve the generalizability of the findings. A longer training duration is also necessary to evaluate the long-term effects of BCT on various physical parameters, such as agility, explosive strength, and injury prevention. Further studies could explore the integration of BCT with other training methods to develop more comprehensive and holistic approaches. Expanding the scope of research will help refine BCT as an innovative and effective training method that meets the needs of athletes across various sports disciplines.

Conclusions

The findings of this study demonstrate that four weeks of bodyweight circuit training (BCT) significantly improve flexibility (49.29%) and strength endurance, including upper body strength endurance (44.27%), abdominal strength endurance (37.64%), and back strength endurance (40.21%). The BCT program can be effectively applied to optimize the physical performance of tennis players.

Additionally, with its design based on natural body movements, BCT provides a comprehensive and relevant training approach not only for tennis players but also for athletes in other sports that require a combination of flexibility, strength, and endurance. This study contributes to the sports training literature, though further research is needed to fully explore the potential benefits of bodyweight circuit training.

Conflict of Interest

The authors declare no competing interests related to this work.

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