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Article

Before and after core strength training: A comparison of smash technique between badminton players

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Abstract: Objective: This paper aims to investigate the impact of core strength training on the smash technique in badminton. **Methods:** Twenty male badminton players were randomly assigned to Group A (core strength training) and Group B (conventional waist and abdominal strength training). They underwent training from 15:00 p.m. to 17:00 p.m. on Monday, Wednesday and Friday. Group A did core strength training exercises such as four-point support and cross-body crunch. Core strength, balance, and related indicators of the smash technique were measured before and after a 12-week experiment for comparative analysis. **Results:** Before the experiment, there were no significant differences in the indicators between the two groups ($p > 0.05$). However, after the experiment, Group A achieved a badminton throw performance of 8.61 ± 0.75 m, a 30s double-rocking rope skipping performance of 48.67 ± 3.77, an one-minute sit-up performance of 58.24 ± 3.71, an eight-level abdominal bridge performance of 3.38 ± 8.15 points, a closed-eye single-foot standing time of 56.12 ± 12.35s, a closed-eye straight-line walking displacement of 17.78 ± 10.12 cm, a batting speed of 145.12 ± 5.97 km/h, and a landing point stability of 34.22 ± 2.31 points, which showed significant differences compared to the performance before the experiment. It also performed better than Group B except for the eight-level abdominal bridge. **Conclusion:** The results indicate that athletes who undergo core strength training show significant improvements in physical fitness and smash ability, proving the reliability of core strength training and its practical application in training.

Keywords: core strength training; smash; balance; badminton player

1. Introduction

Badminton is a racket sport [1] and also an official international level sport [2], involving repetitive jumping, lunging, and quick changes of direction in the lower limbs [3]. Badminton requires athletes to have strong physical fitness [4], with high demands on their speed and strength [5]. As competitive events become increasingly intense [6], research into how to enhance athletes' technical abilities and secure victories has gained significance. The improvement of athletic performance is closely linked to long-term, high-intensity training, and the role and effectiveness of various training methods have been subject to extensive investigation due to the increasing diversity and novelty of these methods [7]. The smash is a crucial technique in badminton. The player jumps up in the air with both feet and strikes the shuttlecock towards the opponent's court area with full force. While most existing badminton-related studies focus on the feature analysis of specific technical movements [8] or investigating injuries [9], there is limited content available regarding core strength training. Therefore, this study compared the physical fitness and smash technique levels of athletes before and after core strength training to verify the reliability of core strength training. The research results provide theoretical

support for the further application of the core strength training method in daily sports training and contribute to the exploration of advanced badminton training means, which is beneficial to promoting the diversity of badminton training methods and achieving the further enhancement of the athletic ability of badminton players.

2. Literature review

The study conducted by Feito et al. [10] investigated the effects of eight weeks of high-intensity functional training on overweight and obese adults and found no significant differences in body composition or blood glucose control compared to eight weeks of aerobic and resistance training. Aksoy [11] analyzed the effects of ten weeks of whole-body vibration (WBV) training on taekwondo athletes and found significant improvements in vertical jump test, seated reach test, and agility t-test in the WBV training group compared to the control group, indicating the positive effects of WBV on strength, flexibility, and agility. Formiga et al. [12] compared the effects of aerobic exercise with and without blood flow restriction (BFR) training and concluded that aerobic exercise with BFR was more favorable for improving aerobic capacity. Nugroho et al. [13] analyzed the impact of intensity and interval of trapping circuit on the physical condition of badminton players and found that a 1:½ interval and 80% intensity yielded optimal training effects, including a strength improvement of 43.78%, a speed improvement of 31.42%, and an agility enhancement of 9.66%. During physical exercise, the core muscles contract to maintain body stability, generating a force known as core strength, which plays a crucial role in energy transfer within the body [14]. Core strength training has become an integral part of training in many sports [15]. Anant et al. [16] analyzed the effects of eight weeks of core strength training on male athletes and observed significant improvements in lateral trunk endurance, leg explosive strength, and abdominal endurance ($p < 0.05$). Samson et al. [17] conducted a six-week experiment and found that core strength training significantly enhanced abdominal and back strength in volleyball players. Turna et al. [18] analyzed the effects of six weeks of core strength training on male athletes and found statistically significant differences in core stability, grip strength, and 30s sit-up test compared to the control group. Ylmaz et al. [19] discovered that core strength training for eight weeks can affect isokinetic knee joint strength at different speeds. The study conducted by Ozmen et al. [20] analyzed the effects of core strength training on dynamic balance, vertical jump height, and throwing velocity in handball players. They found that a six-week core strength training program did not significantly improve dynamic balance, vertical jump height, and throwing velocity. A longer duration of core strength training may be necessary for noticeable improvements in these aspects.

3. Research subjects and methods

3.1. Research subjects

Taking 20 male athletes from the badminton team at Pingdingshan University in Henan province as the subjects, the study randomly divided them into two groups: Group A, which underwent core strength training, and Group B, which underwent

conventional waist and abdominal strength training. **Table 1** presents the demographic information of the two groups.

Table 1. Demographic information.

	Serial number	Age/year	Height/cm	Weight/kg	Training time/year
Group A	1	22	183	75	7
	2	23	184	76	8
	3	22	181	75	7
	4	22	182	76	7
	5	22	183	77	7
	6	23	180	78	7
	7	22	181	75	7
	8	22	185	78	7
	9	22	186	79	6
	10	22	183	78	7
Group B	1	22	185	79	7
	2	22	182	75	7
	3	23	183	75	7
	4	22	181	71	8
	5	23	182	75	7
	6	22	183	75	7
	7	22	184	75	7
	8	22	181	74	6
	9	22	182	75	7
	10	22	181	74	7

3.2. Research methods

To ensure the effectiveness of the experiment, both groups of athletes adhered to the same training schedule, utilized the same training venue and equipment, and were guided by the same coaches. They also followed a uniform accommodation and food plan and were restricted from engaging in any additional training activities outside of the experiment. Furthermore, the measurement of various indicators was conducted by the same researchers. The specific study design is as follows.

(1) Participants and grouping were determined. Relevant information was recorded, and pre-tests were conducted on relevant indicators.

(2) The experiment started and lasted for 12 weeks, with training sessions held uniformly every Monday, Wednesday, and Friday from 15:00 p.m. to 17:00 p.m.. Before each training session, a warm-up routine was mandatory, and relaxation exercises were performed after training to ensure the quality of the training. The two groups adopted different training programs.

(3) Post-tests were performed on relevant indicators at the end of the 12-week training.

(4) The experimental data was organized in Excel and divided into two phases for comparative analysis: pre-experiment (pre-test data) and post-experiment (post-

test data). The data was statistically processed by SPSS 22.0 [21]. The differences in various test indicators before and after the experiment, as well as between groups, were compared. The significance level was set at 0.05 [22].

The training programs for groups A and B were designed by referencing relevant literature on core strength training as well as real-world teaching applications. The specific training programs for both groups are outlined in **Tables 2** and **3**.

Table 2. Core strength training program for Group A.

Time	Element	No. of sets	Movement description
Weeks 1–8	Four-point support	1min/set, 2 sets, a 60s break between groups	Support the ground with both hands, with the front soles of the feet on the ground, forming a 90° angle between the body and thighs and a 90° angle at the knee joint. The front soles of the feet support the ground while keeping the knees suspended, tightening the abdominal muscles, and maintaining even breathing.
	Cross-body crunch	30/set, 2 sets, a 60s break between sets	Lie on a mat, alternate bending and stretching two legs, and keep the lower back pressed against the ground.
	Hip lift and knee bending	20/set, 2 sets, a 60s break between sets	Lie flat on a mat with two arms on either side of the body. The two palms faced downwards. Lift two feet a few centimeters off the ground, and then power the lower abs to tuck the knees toward the head until the hips are off the ground and the thighs are close to the chest. Rest slightly at the top before returning to the initial posture.
	Hanging push-ups	20/set, 2 sets, a 60s break between sets	Support the rings with both hands, slowly lower the body, keep elbows close to the body, then pause for a moment, push the body upwards, and finally return to the initial stance.
Weeks 9–12	Suspension side bridge	20/set, 4 sets, a 60s break between sets	Lying on one side with one foot on a suspension and hips upright. Lift the pelvis off the floor, tighten the abdominals, and keep the spine upright until the body drops.
	Cross-body crunch	30/set, 4 sets, a 60s break between sets	Same as above.
	Exercise ball push-ups	20/set, 4 sets, a 60s break between sets	Both hands are placed on the gym box with fingertips perpendicular to the collarbone, both feet are placed on the gym ball with toes pointed down. The ankles form an angle of 90°. The elbows are slightly flexed to keep the chest in the same position as the legs. Then, the legs are pulled in the direction of the gym box before returning to the initial posture.
	Balance pad one-legged squat	10 times/set for each left and right foot, 4 sets, a 60s break between sets	Stand on a balance mat with one foot and squat with the hip flexed until the whole sole of the supporting foot touches the ground. Stand up and exchange the support leg.

Table 3. Conventional low back and abdominal strength training program for Group B.

Time	Element	No. of sets	Movement description
Weeks 1–8	Plank	1min/group, 2 groups, a 60s break between groups	Lie flat on the mat with your upper arms and forearms at a 90-degree angle and support the body parallel to the ground. Tighten the abdominals, keep the heels perpendicular to the floor, and keep breathing evenly.
	Sit-up	30/set, 2 sets, a 60s break between sets	Lie flat on the back on a mat, cross the legs over the body, bend the lower back and abdomen to rise, and touch the head to the knees.
	Supine leg raise	30/set, 2 sets, a 60s break between sets	Lie on the back on a mat, raise the hips with a lower abdominal thrust, pause briefly at the highest point, and return to the initial posture.
	Superman	30/set, 2 sets, a 60s break between sets	Lie prone on a mat, keep the two legs together, raise arms forward with palms facing downwards, and lift both arms and legs upwards as much as possible. Maintain the movement and return to the initial posture after 3–5s.

Table 3. (*Continued*).

Time	Element	No. of sets	Movement description
Weeks 8–12	Plank	1min/set, 4 sets, a 60s break between sets	Same as above.
	Weight-bearing rotation	30/set, 4 sets, 60s break between sets	Stand with two legs apart at shoulder width, put the horizontal bar of a barbell behind the neck, turn the body to the left and right to the limit, drive the horizontal bar with the waist.
	Dynamic push-ups	15/set, 4 sets, a 60s break between sets	Lie down on the floor, do push-ups, move each foot from side to side.
	Alternate leg raise during lying	30/set, 4 sets, a 60s break between sets	Lie flat on the back on a mat, keep knees straight, and quickly cross the legs high.

(3) After 12 weeks of training, post-tests were conducted to measure relevant indicators for comparative analyses.

The pre-test and post-test used the same testing indicators, as follows,

(1) Physical fitness test indicators

Core strength:

① Badminton throw: Stand behind the baseline of the court, the subject held the ball in his hand and forcefully threw it without crossing the baseline. Repeat twice and record the best performance.

② 30s double shake rope skipping: The subject performed double rope shakes followed by a jump. The number of successful jumps within 30s was recorded, and the test performance was discarded if the jump was interrupted. Repeat the test twice and record the best performance.

③ 1-min sit-ups: The subject lay flat on a mat to perform sit-ups. The number of standard movements completed within one minute was recorded.

④ The eight-stage abdominal bridge: The subject lay prone on a mat and, upon hearing the start command, perform an in-situ plank. The scoring standards are as shown in **Figure 1**. The score of the round before the failed round was taken. The best score was selected from two valid scores as the final score.

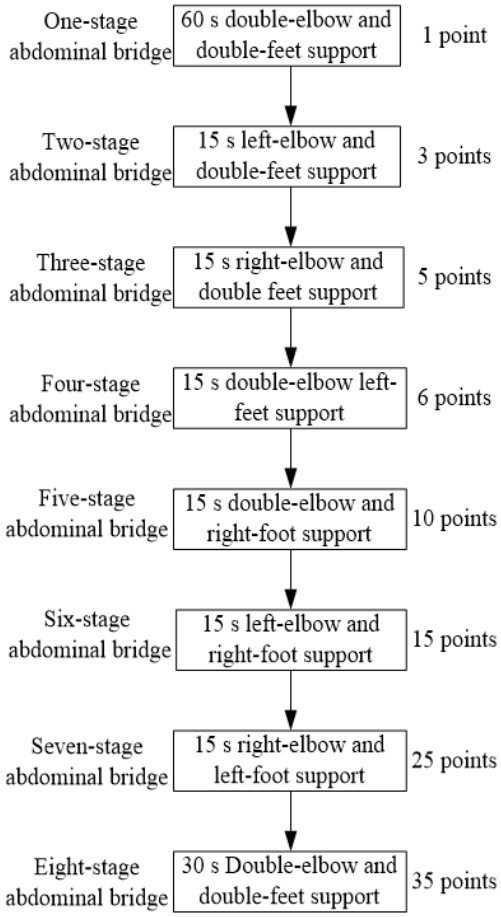

Figure 1. Scoring standards for the eight-stage abdominal bridge.

Balance ability:

① Eyes-closed single-leg standing [23]: The subject stood on one foot with eyes closed. The timer was stopped if the supporting foot moved. Repeat twice and record the best performance.

② Eyes-closed straight-line walking displacement: A 10 m line was marked on the ground. The subject stood at intersection point 1, closed his eyes after determining the direction, and walked straight ahead. When reaching finishing line 1, he stopped and marked this position as deviation point 1. The distance between deviation point 1 and intersection point 2 was denoted by M1. The subject opened his eyes at intersection point 2 with his back facing intersection point 1, then closed his eyes again upon hearing a command to walk backwards until reaching finishing line 2. This position was marked as deviation point 2. The distance between deviation point 2 and intersection point 1 was denoted by M2. The displacement result was calculated by (M1 + M2)/2. The schematic diagram of this test is shown in **Figure 2**. Repeat this test three times and calculate the average displacement.

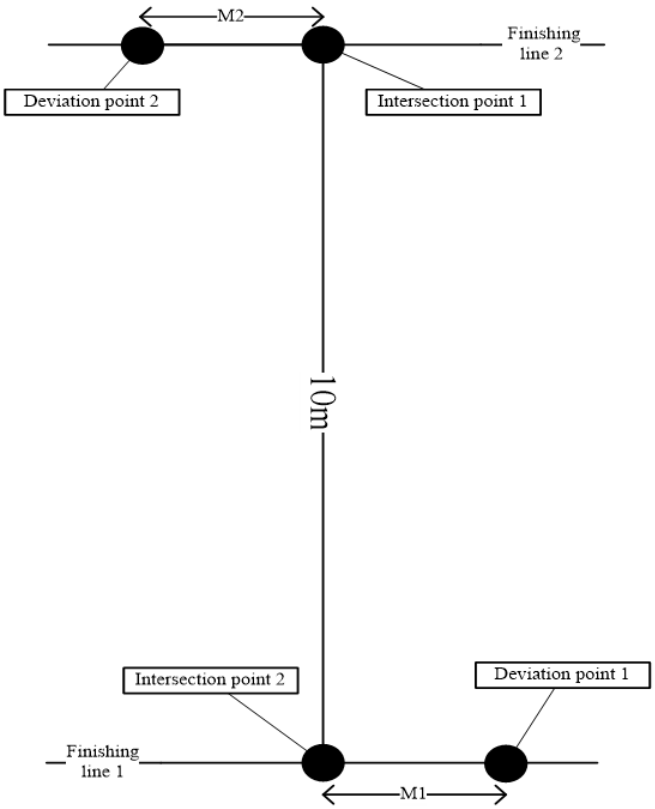

Figure 2. Linear walking displacement with eyes closed.

(2) Test indicators for smash technique

① Stroke speed: The Smart Badminton Sensor 2.0 was attached to the handle of the racket. The player stood in the middle of the court while the server hit the ball to the player's forehand area. The player quickly struck the ball in the air (**Figure 3**). This process was repeated five times, and the best performance was recorded.

Figure 3. The smash movement.

② Placemenet stability: The player stood in the center of the area, while the server stood in the center of the opposite side of the field and served the ball. The

player quickly moved to hit the ball before it landed. Depending on the placement of the ball, a score of 3–5 points was given (**Figure 4**). Each player did ten smashes, and the total score was recorded.

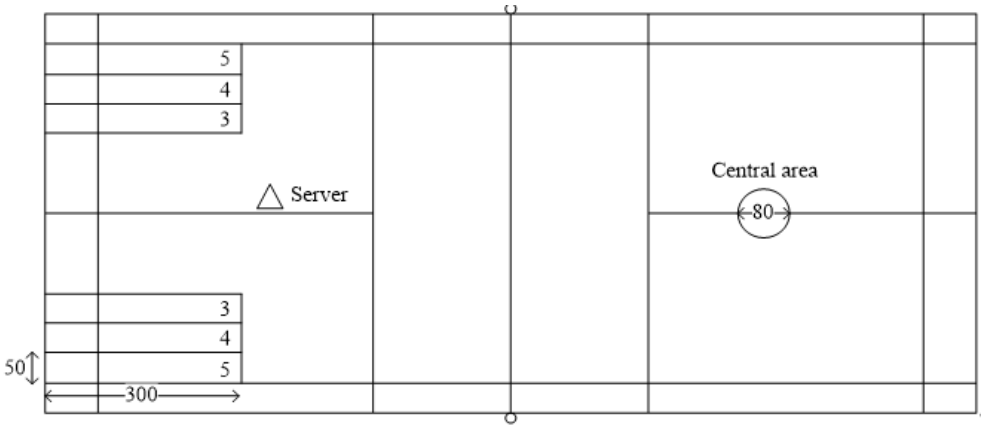

Figure 4. Schematic diagram of placement stability scoring.

4. Results analysis

The indicators of Groups A and B before the experiment are shown in **Table 4**.

Table 4. Comparison of test indicators between the two groups before the experiment.

		Group A (n = 10)	Group B (n = 10)	*p*
Core strength	Badminton throw/m	7.82 ± 0.94	7.89 ± 0.87	0.215
	30s double shake rope skipping/n	29.81 ± 4.21	28.64 ± 3.75	0.321
	1min sit-ups/n	45.21 ± 3.64	44.77 ± 3.55	0.124
	Eight-stage abdominal bridge/point	7.24 ± 5.12	7.87 ± 4.36	0.087
Balance ability	Eyes-closed single-leg standing/s	36.34 ± 13.21	35.46 ± 12.79	0.226
	Eyes-closed straight-line walking displacement/cm	34.87 ± 15.64	35.61 ± 14.95	0.874
Smash	Stroke speed (km/h)	141.77 ± 6.84	141.56 ± 6.96	0.268
	Placement stability/point	32.31 ± 1.96	32.16 ± 2.12	0.654

From **Table 4**, it can be observed that there were no significant differences in the measured indicators between the two groups ($p > 0.05$). This result suggested that before the experiment, there were no significant differences between Group A and Group B in terms of core strength, balance ability, and the technique of smash. Thus, it can be concluded that the two groups were comparable in these aspects.

The indicators of Group A before and after the experiment were compared in **Table 5**.

Table 5. Comparison of indicators in Group A before and after the experiment.

		Before experiment	**After experiment**	***P***
Core strength	Badminton throw/m	7.82 ± 0.94	8.61 ± 0.75	0.012
	30s double shake rope skipping/n	29.81 ± 4.21	48.67 ± 3.77	0.011
	1min sit-ups/n	45.21 ± 3.64	58.24 ± 3.71	0.036
	Eight-stage abdominal bridge/point	7.24 ± 5.12	13.38 ± 8.15	0.021
balance	Eyes-closed single-leg standing/s	36.34 ± 13.21	56.12 ± 12.35	0.031
	Eyes-closed straight-line walking displacement/cm	34.87 ± 15.64	17.78 ± 10.12	0.008
Smash	Stroke speed (km/h)	141.77 ± 6.84	145.12 ± 5.97	0.002
	Placement stability/point	32.31 ± 1.96	34.22 ± 2.31	0.041

From **Table 5**, it can be observed that Group A showed a significant improvement in core strength after the experiment. The badminton throw distance was 8.61 ± 0.75 m (p = 0.012 < 0.05 compared to before experiment), the performance of 30 s double shake rope skipping improved to 48.67 ± 3.77, the one-minute sit-up count increased to 58.24 ± 3.71, and the eight-stage abdominal bridge score was 13.38 ± 8.15 points. All of these improvements were significant (p < 0.05) compared to the pre-experiment measurements, indicating a significant enhancement in core strength. In terms of balance ability, Group A also demonstrated a significant improvement after the experiment. The duration of eyes-closed single-leg standing increased to 56.12 ± 12.35s, which showed a 54.43% increase compared to the pre-experiment value. The eyes-closed straight-line walking displacement was 17.78 ± 10.12 cm, showing a 49.01% reduction compared to the pre-experiment measurement (p < 0.05), indicating a significant enhancement in balance ability. Finally, in terms of the smash technique, the stroke speed increased to 145.12 ± 5.97 km/h, and the placement stability score reached 34.22 ± 2.31 points (p < 0.05 compared to before experiment), indicating an enhancement in the smash technique.

The indicators of group B before and after the experiment were compared in **Table 6**.

Table 6. Comparison of indicators in group B before and after the experiment.

		Before experiment	**After experiment**	***P***
Core strength	Badminton throw/m	7.89 ± 0.87	8.22 ± 0.64	0.033
	30s double shake rope skipping/n	28.64 ± 3.75	37.89 ± 2.25	0.024
	1min sit-ups/n	44.77 ± 3.55	51.78 ± 0.74	0.031
	Eight-stage abdominal bridge/point	7.87 ± 4.36	13.36 ± 7.24	0.021
Balance ability	Eyes-closed single-leg standing/s	35.46 ± 12.79	42.17 ± 12.64	0.007
	Eyes-closed straight-line walking displacement/cm	35.61 ± 14.95	30.21 ± 12.36	0.018
Smash	Stroke speed (km/h)	141.56 ± 6.96	142.37 ± 6.64	0.052
	Placement stability/point	32.16 ± 2.12	32.55 ± 2.35	0.056

From **Table 6**, it can be observed that in Group B, the badminton throw distance increased to 8.22 ± 0.64 m, the performance of 30s double shake rope

skipping improved to 37.89 ± 2.25, the one-minute sit-up count increased to 51.78 ± 0.74, and the eight-stage abdominal bridge score improved to 13.36 ± 7.24 points (all $p < 0.05$ compared to the pre-experiment measurements), indicating an enhancement in core strength. Regarding balance ability, the duration of eyes-closed single-leg standing increased to 42.17 ± 12.64s, and the eyes-closed straight-line walking displacement decreased to 30.21 ± 12.36 cm (both $p < 0.05$ compared to the pre-experiment measurements). However, Group B did not show significant differences in the indicator of the smash technique before and after the experiment ($p > 0.05$). These results suggested that conventional waist and abdominal strength training had a certain effect on the improvement of core strength and balance ability but did not have a substantial impact on the enhancement of smash technique.

The indicators of the two groups after experiment were compared in **Table 7**.

Table 7. Comparison of indicators between the two groups after the experiment.

		Group A (n = 10)	**Group B (n = 10)**	***P***
Core strength	Badminton throw/m	8.61 ± 0.75	8.22 ± 0.64	0.012
	30s double shake rope skipping/n	48.67 ± 3.77	37.89 ± 2.25	0.002
	1min sit-ups/n	58.24 ± 3.71	51.78 ± 0.74	0.013
	Eight-stage abdominal bridge/point	13.38 ± 8.15	13.36 ± 7.24	0.061
Balance ability	Eyes-closed single-leg standing/s	56.12 ± 12.35	42.17 ± 12.64	0.016
	Eyes-closed straight-line walking displacement/cm	17.78 ± 10.12	30.21 ± 12.36	0.014
Smash	Stroke speed (km/h)	145.12 ± 5.97	142.37 ± 6.64	0.007
	Placement stability/point	34.22 ± 2.31	32.55 ± 2.35	0.006

Following the experiment, all the indicators of Groups A and B exhibited certain improvements. However, Groups A and B had some disparities. Firstly, in terms of core strength, the badminton throw distance of Group A was 8.61 ± 0.75 m, which was 4.74% higher than that of Group B. The 30 s double shake rope skipping count was 48.67 ± 3.77, showing an increase of 28.45% compared to Group B. The one-minute sit-up count of Group A was 58.24 ± 3.71, indicating a 12.48% increase compared to Group B. These three indicators exhibited significant differences. However, in the eight-stage abdominal bridge score, the difference between the two groups was not significant ($p > 0.05$). In terms of balance ability, the duration of eyes-closed single-leg standing of Group A was 33.08% longer than that of Group B, and the eyes-closed straight-line walking displacement was 41.15% less than that of Group B ($p < 0.05$). In terms of smash technique, the stroke speed of Group A reached 145.12 ± 5.97 km/h, and the stability of placement point scored 34.22 ± 2.31 points, both higher than those of Group B.

5. Discussion

The core refers to the central muscles of the human body, responsible for stability and support [24]. During exercise, the core muscle groups do not directly participate in the movement but act as a stable base for limb movements. Therefore, improving core strength is beneficial for enhancing core stability [25], thereby enhancing overall body coordination [26], reducing the burden on the limbs, delaying the onset of muscular fatigue, and preventing sports injuries [27]. Core strength training has been proven to relieve sports injuries [28], enhance dynamic balance ability [29], and promote physical health [30]. Therefore, studying the effects of core strength training on badminton players also holds practical significance.

First and foremost, based on the results of the comparison of core strength-related indicators before and after experiment and between groups, it can be concluded that core strength training is more effective for enhancing the core strength of badminton players compared to the conventional waist and abdominal strength training. During core strength training, muscle groups in the athlete's core area is activated more comprehensively. On the other hand, conventional waist and abdominal strength training relies more on the body's contact point with the ground, resulting in less prominent muscle work and less effective training outcomes. Taking the badminton throw as an example, executing the movement requires transferring power from the lower limbs through the core muscle groups to the upper limbs. In this process, the strength and coordination of the core play a significant role. Group A demonstrated a substantial improvement in badminton throw distance compared to Group B.

The results of the balance ability-related indicators further demonstrated that core strength training is superior to conventional waist and abdominal strength training in improving the balance ability of badminton players. Core strength training not only enhances the players' strength but also increases muscle coordination, resulting in improved regulation of the body. As a result, the balance ability is effectively enhanced.

When comparing the smash technique, core strength training was superior to conventional waist and abdominal strength training in improving the level of this technique. Core strength training helps players establish a stable core position before executing the stroke, allowing them to perform the correct hitting movement. It also increases the speed of hip rotation during the racket swing, resulting in more power and higher speed. Furthermore, core strength training enables better control of the placement, leading to better overall performance in hitting the ball. The results demonstrated that Group A achieved a stroke speed of 145.12 ± 5.97 km/h and a placement stability score of 34.22 ± 2.31 points, both of which were superior to Group B. Conversely, Group B did not exhibit significant improvement in the smash technique level after 12 weeks of regular waist and abdominal strength training.

The experimental results indicated that the 12-week core strength training program yields significant improvements in physical fitness and smash technique. It can be further applied in actual training.

6. Conclusion

This paper analyzed the effects of a 12-week core strength training program on badminton players. It was found that Groups A and B had statistically significant differences in all indicators ($p < 0.05$), except for the score of the eighth-grade abdominal bridge. The results highlight the positive effects of core strength training on badminton players. The training program effectively enhances core strength and balance, while also increasing the speed of smashes and improving placement stability. The study provides some reference suggestions for the training of practical badminton athletes and also offers theoretical support for further research on badminton training methods. However, there are limitations in this study, such as the fact that it only investigated 20 male badminton athletes from one school, with a small sample size and limited to males. Therefore, future work will aim to expand the sample size and include female athletes for more in-depth research.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

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