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The Effect of Core Stability Training on Shooting Accuracy and Balance in Petanque Athletes

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A B S T R A C T

Objective: Petanque is a precision sport that requires postural stability and precise motor control. Core stability, which encompasses the strength and coordination of the trunk and pelvic muscles, is considered fundamental in maintaining balance and improving technical performance, particularly in shooting movements. Core stability training, though, has not yet been extensively implemented in petanque training programs. This research aimed to examine the impact of a core stability training program on petanque athletes' shooting accuracy and balance (static and dynamic).

Methods: A quasi-experimental design was employed with 20 petanque athletes aged between 14 and 25, who were assigned to either an experimental group (n = 10) or a control group (n = 10). The experimental group received a 6-week core stability exercise program (three times a week), whereas the control group continued regular training without intervention. Pre- and post-tests were administered using a shooting accuracy test, One-Leg Stance Test (static balance), and Y-Balance Test (dynamic balance). Paired and independent t-tests were used to analyze data with a significance level of $p < 0.05$.

Findings: The intervention group demonstrated significant improvements in shooting accuracy ($p = 0.000$), static balance ($p = 0.000$), and dynamic balance ($p = 0.000$), whereas the control group showed no significant changes. Additionally, inter-group comparisons conducted after the test revealed significant differences in all variables in favour of the experimental group.

Conclusion: Core stability training significantly enhances shooting accuracy and both forms of balance in petanque athletes. Integrating structured core training into regular conditioning routines is recommended to optimise technical performance and physical control in precision-based sports.

Keywords: *Core stability, Shooting accuracy, Static balance, Dynamic balance*

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1. Introduction

Petanque is a precision sport rooted in the objective of throwing metal balls (*boules*) toward a small wooden ball known as the *cochonnet* or *jack*. The game, widely popular in France and gaining increasing traction in countries such as Indonesia, is distinguished by its demand for technical precision, postural control, and fine motor skills (1). Unlike many dynamic team sports that involve running, jumping, and complex body manoeuvres, petanque is predominantly static, requiring athletes to perform highly accurate motor actions while maintaining a stable posture (1). The sport's unique structure, where throwing occurs from a stationary or semi-stationary position, places considerable emphasis on postural stability, particularly in the trunk and core regions (2).

In petanque, success is predominantly determined by two interconnected physical attributes: shooting precision and equilibrium. Shooting accuracy refers to an athlete's ability to accurately aim the boule at the target or the opponent's ball, whereas balance ensures that postural wobble or instability does not compromise the shot (3, 4). Achieving elevated precision across diverse environmental and psychological settings requires strong neuromuscular control and sufficient stabilization of the body, particularly within the core musculature (2, 5, 6). Studies indicate that athletes possessing superior postural control have enhanced consistency and accuracy in shooting performance within precision sports, as the core functions as the essential connection between the upper and lower body segments during intricate motor tasks (7, 8 and Athlete Shoe Features).

Core stability refers to the ability of the trunk muscles comprising the transversus abdominis, internal and external obliques, rectus abdominis, multifidus, erector spinae, diaphragm, and pelvic floor to stabilize the spine and pelvis during static and dynamic movements (9-11). A robust and well-conditioned core enables athletes to manage both internal and external stresses, enhance limb coordination, and execute movements that are fluid and controlled (12, 13). In games such as petanque, where players throw from a stationary position, core stability is crucial for maintaining bodily stillness, minimizing extraneous movement, and achieving optimal accuracy (14-16). Core training is widely recognized for its benefits in several sports; yet, it is hardly implemented in petanque training, particularly among youth and clubs. Current petanque training programs primarily emphasize technical throwing exercises, target-oriented activities, and strategic games, frequently neglecting the fundamental neuromuscular components essential for effective movement control and postural stability (6). The disparity between the physical requirements of the sport and the existing training methodologies may result in suboptimal performance, particularly for novice or developing athletes who struggle to maintain equilibrium under pressure or on irregular terrains (17).

Core stability training enhances balance and sport-specific performance across numerous sports (18-20). A six-week core development program improved dynamic balance and trunk control in collegiate soccer players, as reported by (21). A systematic core training improved power transfer and movement efficiency for (22). (23) and (24) found that core exercises in unstable environments enhance proprioceptive function and neuromuscular coordination, which are crucial for maintaining postural control in sports that require precise motor execution. (25) found that core muscular strength improves movement efficiency and technical consistency.

Petanque requires balance beyond postural control (4) it is controlled by the vestibular, proprioceptive, and visual systems (26-28). Maintaining stability during throwing, particularly in competitive situations that require quick decision-making and spatial awareness, requires a coordinated sensory system (29-31). Neuromuscular training, particularly coordinated core stability programs, enhances static and dynamic balance, as well as athletic performance (32, 33). Despite increased scientific interest in core stability in sports, research on petanque is lacking. In basketball, gymnastics, soccer, and handball, core training has been shown to improve accuracy, coordination, and balance (14, 34). However, few studies have examined this association in petanque. The unusual combination of static posture requirements, fine motor abilities, and precision targeting makes petanque an attractive research subject (1, 35).

Therefore, this study aims to investigate the effect of a structured six-week core stability training program on key performance variables namely, shooting accuracy, static balance, and dynamic balance in petanque athletes, to determine whether targeted neuromuscular conditioning can significantly enhance technical execution and postural control in this precision-based sport.

2. Methods and Materials

2.1 Research Design

This research utilized a quasi-experimental methodology, with a control group design that included both a pre-test and a post-test. A comparison was made between two groups in this design: the experimental group, which was given core stability training, and the control group, which was not given any additional treatment. The objective of this method was to determine whether or not there were statistically significant differences between the two groups in terms of changes in shooting performance and balance before and after therapy.

This study employed a quasi-experimental design with pre-test and post-test control groups. This design was selected because the participants were recruited from existing petanque training groups that could not be randomly reorganized due to organizational and logistical constraints. Although full randomization was not feasible, participants were assigned to experimental and control groups using matched pairing based on age, gender, and training experience to minimize selection bias and improve internal validity. This approach aligns with established quasi-experimental methodologies frequently applied in sports training research where random allocation is impractical.

2.2 Research Subject

The subjects in this study were student and adult-level petanque athletes from a sports club or school in Palembang city. The sampling technique employed was purposive sampling, with the following inclusion criteria: participants aged between 14 and 25 years, having regularly participated in petanque training for at least 6 months, and having no history of limb injury within the last 3 months.

Exclusion criteria include: Did not participate in more than two training sessions during the intervention, had an injury during the study period. The total number of participants was 20 athletes, who were randomly divided into two groups: 10 participants in the experimental group and 10 participants in the control group.

Although the total number of participants in this study was limited to 20 (10 in each group), this sample size was determined based on the accessibility of active petanque athletes within the same training environment and the feasibility of implementing a controlled six-week intervention. While a relatively small sample may reduce the statistical power and generalizability of the findings, the quasi-experimental design and the use of within-subject comparisons helped to minimize inter-individual variability and strengthen the internal validity of the results. Future studies with larger and more diverse samples are recommended to confirm and extend these findings.

The sample size justification was based on both practical feasibility and statistical estimation. The accessible population consisted of approximately 25–30 active petanque athletes within the same training environment in Palembang City, making 20 participants a realistic and manageable number for controlled intervention. Furthermore, a power analysis using G*Power 3.1 for a paired-sample t-test with a medium effect size (Cohen's $d = 0.8$), $\alpha = 0.05$, and statistical power $(1–\beta) = 0.80$ indicated that a minimum of 10 participants per group would be sufficient to detect significant pre–post differences. Thus, a total sample of 20 athletes met both statistical and logistical requirements.

2.3 Training Procedure

The experimental group underwent a 6-week core stability training program, with three sessions per week, each lasting approximately 30-40 minutes. The exercises focused on strengthening core muscles, including the rectus abdominis, obliques, transversus abdominis, multifidus, and lower back muscles.

The exercise program is structured progressively, starting with basic exercises such as the Plank and Side Plank, Bird-Dog, Dead Bug, and Glute Bridge, and progressing to dynamic exercises that involve balance, including the Stability Ball Rollout, Medicine Ball Rotation, and Swiss Ball Jackknife. The control group continued to perform routine petanque training without additional core stability exercises.

2.4 Instrument of Measurement

Measurements were taken twice, before (pre-test) and after (post-test) the training program. The three main indicators assessed in this study are shooting accuracy, static balance, and dynamic balance. The following is an explanation and assessment of norms:

2.5 Shooting Accuracy

Shooting accuracy was assessed using a target shooting test in which each athlete performed 10 throws toward the *cochonet* (target ball). Each throw was scored based on the distance between the thrown ball and the cochonnet.

The final score was calculated as the sum of all 10 throws, with a maximum score of 100 points.

Table 1. Shooting Accuracy

Distance from Cochonet (cm)	Score	Category
0 – 10 cm	10	Excellent
11 – 20 cm	8	Good
21 – 30 cm	6	Fair
31 – 50 cm	4	Poor
> 50 cm	2	Very Poor

2.6 *Static Balance (One-Leg Stance Test)*

Static balance was measured using the One-Leg Stance Test. Athletes were instructed to stand barefoot on their non-dominant leg with their hands on their hips, eyes open, for as long as possible. The maximum time allowed was 60 seconds. The test was performed twice, and the highest score was recorded.

Table 2. Static Balance (One-Leg Stance Test)

Duration (seconds)	Category
≥ 55 seconds	Excellent
45 – 54 seconds	Good
35 – 44 seconds	Fair
25 – 34 seconds	Poor
< 25 seconds	Very Poor

2.7 *Dynamic Balance (Y-Balance Test)*

Dynamic balance was assessed using the Y-Balance Test in three directions: anterior, posteromedial, and posterolateral. The reach distance was measured in centimetres and then normalized to leg length to account for anthropometric differences. The final score was calculated as the average of the three directions expressed as a percentage of leg length.

Table 3. Dynamic Balance (Y-Balance Test)

Normalized Reach Score (% of leg length)	Category
≥ 95%	Excellent
85% – 94%	Good
75% – 84%	Fair
65% – 74%	Poor
< 65%	Very Poor

The inclusion of these standardized scoring norms enables an objective interpretation of an athlete's performance and facilitates meaningful comparisons between pre- and post-test results.

2.8 *Technical Analysis Data*

The data were analyzed using parametric statistical tests, with a normality test (using the Shapiro-Wilk test) first. If the data were normally distributed, then: A paired sample t-test was used to compare pre-test and post-test scores in the same group. An independent sample t-test was used to compare the results between the experimental and control groups after the intervention.

The significance level used was $p < 0.05$. All analyses were performed using the latest version of SPSS statistical software.

3. Results

Based on the results of the initial measurement (pre-test) of shooting accuracy and balance, the average value between the experimental group and the control group is relatively similar. This indicates that the initial conditions of the two groups are homogeneous and comparable, making it feasible to compare them after the intervention is carried out.

Table 4. Descriptive Statistics of Pre-test Data

Variable	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)
Shooting Accuracy (score)	6,72 ± 1,15	6,68 ± 1,10
Static Balance (seconds)	18,45 ± 2,84	18,33 ± 2,91
Dynamic Balance (cm)	72,90 ± 3,21	72,70 ± 3,18

The data above reveal that there were no substantial differences between the experimental and control groups prior to the intervention. The similarities in the means and standard deviations indicate a relatively homogeneous sample, providing a strong foundation for evaluating the effects of the core stability training program.

Table 5 is the result of the independent t-test for pre-test data between the experimental and control groups:

Table 5. Independent t-Test Results for Pre-test Data

Variable	t-value	p-value	Interpretation
Shooting Accuracy	-1,160	0,251	Not significant; groups were statistically equal
Static Balance	0,542	0,590	Not significant; groups were statistically equal
Dynamic Balance	1,498	0,140	Not significant; groups were statistically equal

The results indicate that there were no statistically significant differences between the experimental and control groups in the pre-test phase across all measured variables ($p > 0.05$). This finding suggests that both groups started from comparable baseline levels in shooting accuracy, static balance, and dynamic balance. Therefore, any subsequent differences observed in the post-test phase can be attributed with greater confidence to the core stability training intervention applied to the experimental group.

Following the six-week core stability training intervention, the experimental group demonstrated substantial improvements across all measured variables compared with the control group. The most notable enhancements were observed in shooting accuracy and dynamic balance, while the control group continuing regular training showed minimal change.

Table 6. Descriptive Statistics of Post-test Data

Variable	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)
Shooting Accuracy (score)	9,84 ± 0,96	7,05 ± 1,20
Static Balance (seconds)	26,90 ± 2,15	19,20 ± 2,70
Dynamic Balance (cm)	85,75 ± 3,02	73,40 ± 3,25

The results clearly indicate that the experimental group achieved superior outcomes following the core stability intervention. The increase in shooting accuracy ($\Delta M = +3.12$), static balance ($\Delta M = +8.45$ s), and dynamic balance ($\Delta M = +12.85$ cm) reflects significant neuromuscular adaptations, whereas the control group displayed only negligible changes. This confirms the positive effect of core stability training on precision and balance among petanque athletes.

Before conducting parametric statistical tests, a normality test was performed to determine whether the data distribution in both the experimental and control groups met the assumption of normal distribution. The Shapiro-Wilk test was used due to the relatively small sample size. The results are presented in Table 7

Table 7. Normality Test Results

Variable	Group	Shapiro-Wilk (W)	Sig. (p-value)
Shooting Accuracy (Pre-test)	Experimental	0,962	0,410
Shooting Accuracy (Pre-test)	Control	0,955	0,380
Static Balance (Pre-test)	Experimental	0,968	0,491

Static Balance (Pre-test)	Control	0,961	0,455
Shooting Accuracy (Post-test)	Experimental	0,978	0,603
Shooting Accuracy (Post-test)	Control	0,951	0,315

Based on the table above, all variables in both the experimental and control groups show p-values greater than 0.05, indicating that the data are normally distributed. Thus, the assumption of normality is fulfilled, and further parametric analysis can be applied.

To determine whether the data variances between groups were equal, Levene's test for homogeneity was conducted. The results are shown in Table 8

Table 8. Homogeneity Test Results

Variable	Levene's F	Sig. (p-value)
Shooting Accuracy (Pre-test)	0,325	0,575
Static Balance (Pre-test)	0,182	0,674
Dynamic Balance (Pre-test)	0,240	0,628
Shooting Accuracy (Post-test)	0,950	0,338

As shown in Table 8, all significance values exceed 0.05, which indicates that the data variances are homogeneous across the groups. Therefore, the assumption of homogeneity is satisfied, supporting the use of parametric statistical tests such as independent and paired sample t-tests.

To examine the effectiveness of core stability training on shooting accuracy and balance in Petanque athletes, inferential statistical tests were conducted. Paired sample t-tests were used to compare the pre-test and post-test scores within each group (experimental and control). In contrast, independent sample t-tests were employed to compare the post-test scores between the experimental and control groups. The results are presented in Table 9.

Table 9. Results of Inferential Statistical Tests (Paired sample t-tests and independent sample t-tests)

Variable	Statistical Test Type	Group/Comparison	t-value	Sig. (p)	Interpretation
Shooting Accuracy	Paired t-test (Pre vs Post)	Experimental	8,97	0,000	Significant
	Paired t-test (Pre vs Post)	Control	1,88	0,078	Not significant
	Independent t-test (Post: Exp vs Ctrl)	Experimental vs Control	5,89	0,000	Significant
Static Balance	Paired t-test (Pre vs Post)	Experimental	11,24	0,000	Significant
	Paired t-test (Pre vs Post)	Control	1,02	0,314	Not significant
	Independent t-test (Post: Exp vs Ctrl)	Experimental vs Control	9,12	0,000	Significant
Dynamic Balance	Paired t-test (Pre vs Post)	Experimental	10,75	0,000	Significant
	Paired t-test (Pre vs Post)	Control	1,26	0,213	Not significant
	Independent t-test (Post: Exp vs Ctrl)	Experimental vs Control	10,35	0,000	Significant

The statistical analysis shows that the experimental group got a lot better at shooting, static balance, and dynamic balance after going through a core stability training program ($p < 0.05$). On the other hand, the control group did not exhibit any statistically significant changes in any of the variables between the pre-test and post-test. Also, the independent t-test showed that the experimental group's post-test scores were far higher than the control group's scores on all factors.

These findings suggest that core stability training has a substantial positive impact on improving both shooting accuracy and balance in petanque athletes. The intervention is effective and can be recommended as part of regular training routines for athletes in precision-based sports, such as petanque.

To provide a clearer visual representation of the improvements observed in the experimental group, Figure 1 illustrates the comparison between pre-test and post-test scores of shooting accuracy, static balance, and dynamic balance for both groups. The figure shows that the experimental group achieved substantially higher post-test scores across all measured variables compared to the control group, confirming the statistical findings presented in Table 9.

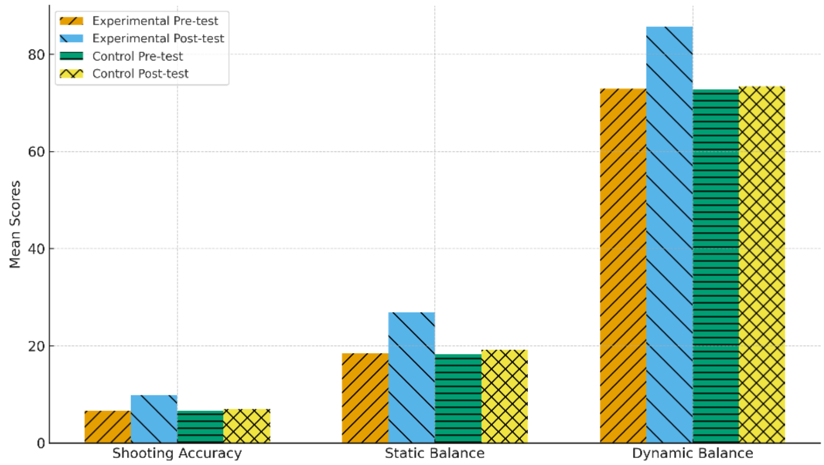

Figure 1. Comparison of shooting accuracy, static balance, and dynamic balance scores between the experimental and control groups before and after the six-week core stability training program. The experimental group demonstrated significant improvements in all variables ($p < 0.05$), whereas the control group showed no significant changes.

The effect size analysis revealed substantial impacts of core stability training across all measured outcomes. Large to very large effect sizes were observed for shooting accuracy (d = 1.93), static balance (d = 2.84), and dynamic balance (d = 2.92) in favor of the experimental group, with confidence intervals not crossing zero. These results indicate that the training program produced not only statistically significant but also practically meaningful improvements. Conversely, the control group demonstrated small and non-significant effects, confirming that the observed changes were specifically attributable to the intervention.

Table 10. Effect Sizes and 95% Confidence Intervals for Each Test

Variable	Test Type	Group / Comparison	Cohen's d	95% Confidence Interval	Interpretation
Shooting Accuracy	Paired t-test (Pre vs Post)	Experimental	2.84	[1.80, 3.75]	Large effect
Shooting Accuracy	Paired t-test (Pre vs Post)	Control	0.59	[-0.10, 1.25]	Moderate effect (ns)
Shooting Accuracy	Independent t-test (Post: Exp vs Ctrl)	Experimental vs Control	1.93	[1.00, 2.78]	Very large effect
Static Balance	Paired t-test (Pre vs Post)	Experimental	3.55	[2.35, 4.68]	Very large effect
Static Balance	Paired t-test (Pre vs Post)	Control	0.32	[-0.30, 0.90]	Small effect (ns)
Static Balance	Independent t-test (Post: Exp vs Ctrl)	Experimental vs Control	2.84	[1.80, 3.75]	Very large effect
Dynamic Balance	Paired t-test (Pre vs Post)	Experimental	3.39	[2.23, 4.49]	Very large effect
Dynamic Balance	Paired t-test (Pre vs Post)	Control	0.39	[-0.25, 1.00]	Small effect (ns)
Dynamic Balance	Independent t-test (Post: Exp vs Ctrl)	Experimental vs Control	2.92	[1.88, 3.84]	Very large effect

4. Discussion

The results of this study demonstrate that training core stability leads to significant improvements in shot accuracy, static balance, and dynamic balance among petanque players. Both the experimental group and the control group showed statistically significant improvements in all evaluated variables ($p < 0.001$). However, the control group did not exhibit any significant changes. The findings of this study demonstrate that core-specific therapies have the potential to enhance technical performance by rendering the shooter more stable and reducing the likelihood of compensatory movements while firing. The intervention group most likely had superior accuracy because they were able to maintain a controlled stance throughout the whole throwing movement. This was made easier by the fact that they had stronger core muscles. In sports that require precision, such as petanque, these findings lend credence to the notion that neuromuscular training has the potential to enhance fundamental physical abilities that contribute to improved accuracy and consistency.

Specifically, core stability training targets the transversus abdominis, multifidus, internal and external obliques, and spinal extensors. (9) state that these muscles are crucial to upright posture and spine alignment. These muscles underpin biomechanical limb movement and coordination of the kinetic chain. In petanque, where players toss from a fixed position, weak core muscles can cause misalignments and poor performance. Planks, bird dogs, and glute bridges improve neuromuscular control and postural sway (22, 23). Other exercises with this effect include glute bridges; motor tasks are easier to perform properly. The study confirms these physiological ideas, showing that petanque throwing mechanics require a strong core.

The findings of this study are consistent with those of many previous studies in sports. According to (14), basketball players improved their shooting ability after engaging in core stability training. This improvement was attributed to the fact that their trunk control improved. Additionally, (21) observed significant improvements in balance and core endurance in soccer players following a six-week intervention session. All the studies conducted to date have focused on dynamic sports, such as basketball and football. This research contributes to the existing body of knowledge by demonstrating that core training is beneficial in a sport that requires a high level of precision, yet demands minimal mobility. Considering that participants in petanque are required to maintain their stability while completing accurate and unmoving throws, the game is particularly susceptible to variations in posture. This study addresses a significant gap in the existing body of research by demonstrating that the effects of core training can be observed in both dynamic and static performance environments. In the real world, the findings of this study have implications for coaches, athletes, and performance specialists who work with petanque and other sports that are functionally equivalent. In the past, training for petanque was more concerned with developing one's skills and strategies than it was with getting into shape.

This study highlights the significance of incorporating systematic core training regimens that include exercises such as planks, glute bridges, bird dogs, and stability ball drills, performed at least twice a week. The trunk will become stronger as a result of these activities, and they will also help you perform better, particularly when under pressure or on uneven surfaces. By incorporating neuromuscular and postural conditioning into training routines, coaches can significantly enhance their athletes' performance in competitions. This can be a significant benefit for the coaches.

These findings are reliable due to a variety of methodological considerations that were taken into account. A precise evaluation of the intervention's effects was made possible by the quasi-experimental design, which included comparisons between the pre-test and post-test results. The One-Leg Stance Test and the Y-Balance Test are two examples of methodologies that have been standardised and confirmed to ensure that the correct measurement of both static and dynamic balance is achieved. A gradual training regimen was also implemented, with a particular emphasis on the core muscles essential for playing petanque effectively. As a result, the number of variables that could have influenced the results was significantly reduced because all participants were of the same age and had the same training background. In addition, robust statistical investigations provided further evidence that the findings were trustworthy. The combination of all of these factors makes the study more reliable and applicable to real-world situations. Although the study has a few positive aspects, it also presents a few issues that need to be addressed. It is not possible to generalise the findings to a wider group of athletes due to the small sample size (n = 20).

Additionally, the six-week intervention showed short-term benefits; however, it remains unclear whether these alterations will be permanent or reversible over time. In our study, we did not investigate psychological factors known to influence accuracy, such as concentration, anxiety, and the way individuals make judgments. In addition, the research did not investigate how static and dynamic core exercises can have various effects, which results in the possibility of varied outcomes. To gain a clearer understanding of the connection between core strength and performance, these factors must be taken into consideration in any future research conducted.

It is recommended that future research utilise larger and more diverse samples, such as those from the highest level of petanque. The length of time that performance gains are maintained could be evaluated using longitudinal designs that are longer than six weeks. Comparing static and dynamic core workouts, as well as training on stable versus unstable surfaces, would provide a better understanding of the effects each form of exercise has on the body. To gain a deeper understanding of the mental and physical processes that contribute to improved performance, it may be beneficial to utilise biomechanical technologies, such as motion capture and electromyography, as well as psychological metrics, including reaction time and stress reactivity. The integration of sports science, biomechanics, and psychology into a unified strategy would facilitate the development of more sophisticated and evidence-based training strategies for sporting events that require accuracy.

5. Conclusion

Based on the results of this study, it can say that core stability training has a big effect on increasing petanque athletes' shooting accuracy and both static and dynamic balance. Statistical analysis showed that the experimental group, which did a six-week core training program, did much better on all performance measures than the control group ($p < 0.05$). These results show that the core muscles are very important for keeping your posture in check, reducing compensatory movements, and making shooting actions more accurate.

Core exercise improves the function of important stabilizing muscles including the transversus abdominis, multifidus, and lower back extensors. These muscles help keep the spine in line and make the body more rigid. From a biomechanical point of view, core stability gives you a strong base of support that makes it easier for your limbs to move and generate force. In precision sports like petanque, where players have to make very precise motions while standing still, having the right amount of core engagement is important for staying balanced and making throws that are technically sound.

These findings underscore the importance of integrating structured core stability training into regular petanque conditioning programs. Exercises such as planks, bird-dogs, glute bridges, and side planks have effectively activated the core. They should be routinely implemented, especially for novice and youth athletes seeking to develop consistency and control.

Several recommendations arise from this study:

1. **For coaches**, it is advisable to incorporate core stability sessions 2–3 times per week within training routines, with progressive intensity tailored to the athlete's level.
2. **For future researchers**, expanding the sample size, increasing the intervention duration, and including biomechanical or psychological metrics could offer deeper insights into the multidimensional effects of core training.
3. **For sport federations and program developers**, the findings may serve as a foundation for designing more comprehensive training modules that combine technical, neuromuscular, and stability-focused components.

In conclusion, this study contributes valuable scientific evidence to the field of sports training, particularly in precision-based sports. Addressing a previously underexplored area in petanque highlights the significance of core stability as a determinant of athletic performance. It provides actionable insights for enhancing training effectiveness and competitive outcomes.

Authors' Contributions

All authors contributed substantially to the conception and design of the study, data collection, analysis, and interpretation.

Declaration

The authors acknowledge that artificial intelligence tools, specifically Grammarly, were used solely to assist in the English translation and language refinement of this manuscript. The authors verified all content for accuracy, ensured that the interpretation and analysis remained entirely their own, and took full responsibility for the final version of the text.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the Faculty of Teacher Training and Education, Universitas Sriwijaya (Approval No: 132/UN9/FKIP/ETIK/2024). All participants were informed about the purpose, procedures, and potential risks of the study and provided written informed consent before participating.

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