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The influence of arm strength-flexibility and problem-solving on Petanque athletes' motor skills: implications for sports learning

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ABSTRACT

This study investigates the direct and indirect effects of arm muscle strength, wrist flexibility, and problem-solving ability on shooting accuracy among female Petanque athletes in West Sumatra. Forty athletes were purposively sampled based on active participation in training and competition. Arm muscle strength was measured using a medicine ball throw, wrist flexibility with a goniometer, problem-solving ability via a Likert-scale questionnaire, and shooting accuracy using the standardized FIPJP test. Path analysis revealed that wrist flexibility ($\beta = 0.324$, $p = 0.046$) and problem-solving ability ($\beta = 0.329$, $p = 0.026$) significantly contribute to shooting accuracy, while arm muscle strength showed a positive but non-significant effect ($\beta = 0.269$, $p = 0.071$). Wrist flexibility also significantly influenced problem-solving ability ($\beta = 0.519$, $p = 0.003$), indicating an indirect pathway. These findings suggest that precision-based performance in Petanque relies more on fine motor control and cognitive decision-making than brute strength, and that training programs should emphasize wrist mobility and cognitive drills. Future research should expand participant diversity, include additional physical and psychological factors, and adopt longitudinal or experimental designs to clarify causal relationships.

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Introduction

Sports play a fundamental role in the development of individuals and societies, transcending boundaries of age, gender, ethnicity, and social status (Núñez & Portela-Pino, 2024). Beyond providing physical benefits, sports contribute to psychological, social, and cultural enrichment, fostering discipline, teamwork, national identity, and personal growth (Di Palma et al., 2018; Li & Moosbrugger, 2021). The growing recognition of sports' multidimensional value has prompted many countries to invest in structured training, athlete development programs, and scientific research to enhance performance.

Petanque is one of the precision-based sports gaining international attention, now included in both national and international competitions (Nasution et al., 2023; Nurhasan et al., 2024). The game is played on gravel or hard dirt surfaces, where athletes throw hollow metal balls, called boules, toward a smaller target ball, the jack or cochonnet. Petanque involves two main techniques: pointing, which places the boule near the jack, and shooting, which strikes an opponent's boule to remove it from a favorable position.

Of these techniques, shooting is considered more technically demanding, requiring a combination of power, control, coordination, timing, and judgment (Zulbahri et al., 2024). The effectiveness of shooting depends not only on physical attributes but also on cognitive decision-making, as athletes must quickly evaluate tactical options under dynamic game conditions (Irawan et al., 2024; Pelana et al., 2021).

Muscle strength, particularly in the upper limbs, plays a crucial role in generating stable throws (Bauer et al., 2022; Sinka et al., 2024). Strong arm muscles allow athletes to control the movement of the boule, adjust throwing force to distance and target requirements, and maintain accuracy throughout repetitive throws (Pratama et al., 2024; Helmi et al., 2024). Insufficient strength can lead to inconsistencies and reduced precision in shooting performance.

Wrist flexibility is another critical factor influencing shooting accuracy. The wrist plays a key role in the final phase of the throw, controlling the release angle, spin, and direction of the boule (Agustina et al., 2025). Flexible wrists enable smoother motion, greater control, and reduced risk of overuse injuries, while limited mobility can result in misdirected shots and less consistent performance.

Cognitive skills, such as problem-solving ability, are equally important in high-pressure sports environments. Problem-solving refers to an athlete's capacity to analyze situations, make rapid decisions, and adapt strategies in response to changing game dynamics (Putra et al., 2024). In Petanque, effective decision-making determines whether to shoot or point, which boule to target, and how much force to apply, all within a few seconds.

Despite recognition of the importance of physical and cognitive factors, existing research on Petanque has largely examined these elements separately, with limited empirical evidence on how arm muscle strength, wrist flexibility, and problem-solving ability interact to influence shooting accuracy. This gap is particularly evident for female athletes in regions such as West Sumatra, where structured scientific investigations are scarce.

This study aims to address these gaps by investigating the direct and indirect effects of arm muscle strength, wrist flexibility, and problem-solving ability on shooting accuracy in female Petanque athletes. Understanding these relationships will provide practical insights for designing holistic training programs that integrate physical and cognitive conditioning and will contribute to the empirical literature on multidimensional performance in precision-based sports.

Method

This study employed a quantitative research design using path analysis to examine both direct and indirect effects among the independent and dependent variables. Path analysis was selected because it allows for the examination of causal relationships within a theoretical model, showing how each variable contributes to shooting accuracy among female Petanque athletes. The variables included arm muscle strength, wrist flexibility, and problem-solving ability as independent and mediating variables, while shooting accuracy served as the dependent variable.

The population consisted of all female Petanque athletes in West Sumatra. A purposive sampling technique was used to select 40 athletes actively participating in training and competitions. This approach was chosen for efficiency and to ensure participants met specific criteria relevant to the research objectives. However, purposive sampling limits the generalizability of findings beyond the selected population.

Data collection utilized four instruments. Arm muscle strength was measured using the medicine ball throw test from a seated position, recording the farthest distance of three attempts. Wrist

flexibility was assessed with a goniometer, measuring maximum wrist flexion angles. Problem-solving ability was evaluated via a 53-item Likert-scale questionnaire covering five indicators, with established reliability and validity (Cronbach's alpha > 0.7). Shooting accuracy was assessed using the standardized FIPJP Precision Shooting test across five stations, scoring 0–5 based on shot precision and outcome. Inter-rater reliability was ensured by having two trained evaluators independently assess shooting performance.

Data analysis included both descriptive and inferential statistics. Descriptive statistics summarized variable characteristics using mean, standard deviation, and frequency distribution. Inferential analysis employed path analysis to determine causal relationships. Prior to analysis, assumption testing was conducted, including normality (Kolmogorov-Smirnov), linearity, multicollinearity, and homoscedasticity, to ensure validity of regression-based analyses. SPSS version 30 was used for all statistical procedures.

This methodological approach allows examination of both direct and indirect effects while acknowledging potential limitations due to small sample size, cross-sectional design, and context-specific participant selection. Future studies should consider longitudinal or experimental designs to strengthen causal inferences and broader generalizability.

Results and Discussions

This study was conducted by examining the contribution of several variables through a series of statistical tests. Prior to the main analysis, the data were tested for normality and linearity to ensure that the assumptions required for further analysis were met.

Normality Test

To ensure the appropriateness of further parametric statistical analysis, the normality of the data for each variable was first tested. Normality testing is crucial because many statistical techniques assume that the data originate from a population following a normal distribution. In this study, the Kolmogorov-Smirnov test was employed using SPSS version 30, with a significance threshold of 0.05. Variables with p-values greater than this threshold indicate that their data distribution does not significantly deviate from normality. The results of these tests for arm muscle strength, wrist flexibility, problem-solving ability, and shooting accuracy are summarized in the following table 1.

Table 1. Normality Test Results

Variable	N	Test Statistic	P-Value	Interpretation
Arm Muscle Strength (X1)	40	0.136	0.061	Normal
Wrist Flexibility (X2)		0.136	0.056	
Problem-Solving Ability (X3)		0.123	0.126	
Shooting Accuracy Ability (Y)		0.098	0.417	

As shown in the table, all variables yielded p-values exceeding the 0.05 threshold, indicating that the assumption of normality is met for all the measured variables. This finding supports the use of parametric methods in the subsequent analysis, ensuring the validity and reliability of the statistical inferences drawn from the data.

Linearity Test

Following the confirmation of normal data distribution, the study proceeded to examine the linearity between the independent variables arm muscle strength, wrist flexibility, and problem-solving ability — and the dependent variable, shooting accuracy. Linearity testing verifies whether the relationship between variables can be appropriately modeled by a linear function, a fundamental assumption in regression analysis. Using SPSS version 30, the linearity of each relationship was tested by comparing the F-value and corresponding p-value to a significance level of 0.05. The results of these tests are presented in the table 2 below.

Table 2. Linearity Test Results

Relationship	F-Value	P-Value	Interpretation
Arm Muscle Strength (X1) → Problem-Solving Ability (X3)	0.585	0.879	Linear
Wrist Flexibility (X2) → Problem-Solving Ability (X3)	0.653	0.688	
Arm Muscle Strength (X1) → Shooting Accuracy (Y)	1.001	0.520	
Wrist Flexibility (X2) → Shooting Accuracy (Y)	1.105	0.381	
Problem-Solving Ability (X3) → Shooting Accuracy (Y)	1.750	0.114	

The linearity test results demonstrated that all relationships between the independent variables and shooting accuracy are linear, as indicated by p-values above the significance level of 0.05. This confirms that linear regression models can be reliably used to further explore how arm muscle strength, wrist flexibility, and problem-solving ability influence shooting accuracy. These findings pave the way for more detailed analyses of the predictive power and contribution of each variable in subsequent sections.

Hypothesis Testing in the Research (Path Analysis)

This study employs path analysis to test the hypotheses regarding the factors influencing the shooting accuracy ability of petanque athletes in West Sumatra. The hypothesis testing was carried out in two stages using structural equation modeling. The first structural model involved three exogenous variables: Arm Muscle Strength (X1), Wrist Flexibility (X2), and Problem-Solving Ability (X3). The second structural model expanded this framework by including the dependent variable, Shooting Accuracy Ability (Y), in addition to the three previously mentioned variables. By analyzing these two structural models, the path coefficients among variables were calculated to provide clear insights into the relationships and to address the research hypotheses comprehensively.

Table 3. Hypothesis Test Results

Model	Variables	Beta Coefficient	Sig.	P-Value	Description
Structural 1	X1 → X3 (p31)	0.289	0.080	0.05	Not Significant
	X2 → X3 (p32)	0.519	0.003		Significant
Structural 2	X1 → Y (py1)	0.269	0.071		Not Significant
	X2 → Y (py2)	0.324	0.046		Significant
	X3 → Y (py3)	0.329	0.026		Significant

Based on the results of hypothesis testing in Structural Model 1, it can be concluded that Wrist Flexibility (X2) has a significant influence on Problem-Solving Ability (X3), as indicated by a beta coefficient of 0.519 with a p-value of 0.003 ($p < 0.05$). In contrast, Arm Muscle Strength (X1) does not have a significant effect on Problem-Solving Ability, with a beta coefficient of 0.289 and a p-value of 0.080 ($p > 0.05$). This suggests that wrist flexibility is more influential than arm muscle strength in developing athletes' ability to solve problems during shooting activities in petanque. In Structural Model 2, which incorporates Shooting Accuracy (Y) as the dependent variable, the analysis shows that Wrist Flexibility (X2) and Problem-Solving Ability (X3) significantly affect shooting accuracy, with p-values of 0.046 and 0.026 respectively (both < 0.05). This indicates that both variables contribute positively and significantly to improving shooting performance in petanque athletes. However, Arm Muscle Strength (X1) again shows no significant direct effect on Shooting Accuracy, with a p-value of 0.071 ($p > 0.05$). Although there is a positive relationship, it is not statistically strong enough to be considered significant. This may imply that while muscle strength may support performance physically, it is not a determining factor in precision-based tasks like shooting in petanque, where flexibility and cognitive skills (like problem-solving) play a more dominant role.These findings collectively highlight the importance of enhancing wrist flexibility and cognitive strategies in training programs for petanque athletes to optimize their shooting accuracy.

This study highlights the multidimensional factors influencing shooting performance in precision-based sports such as Petanque. Shooting requires both technical skill and cognitive decision-making,

making it more than a test of physical strength alone. Despite Petanque's growing popularity and inclusion in competitions, empirical studies examining the combination of physical and cognitive determinants, especially in female athletes in regions like West Sumatra, remain limited. This study aimed to fill this gap by investigating the roles of arm muscle strength, wrist flexibility, and problem-solving ability on shooting accuracy.

The results indicate that wrist flexibility significantly affects shooting accuracy and also influences problem-solving ability, suggesting an indirect pathway for improving performance. Flexible wrists allow athletes to control release angles and spin more precisely, supporting consistent shot execution. These findings align with previous research on precision sports, where fine motor control and joint mobility are critical for accuracy (Wilk et al., 2016; Agustina et al., 2025). This emphasizes that targeted flexibility training can enhance both biomechanical efficiency and cognitive adaptability.

Problem-solving ability was also found to significantly contribute to shooting accuracy. Athletes with higher problem-solving skills can make faster and more effective decisions during gameplay, adapting their strategies to dynamic situations such as opponent moves or terrain variations (Putra et al., 2024; Ghorbanzadeh et al., 2025). This supports the growing consensus that cognitive skills are integral, not secondary, to high-level performance in accuracy-based sports.

Contrary to expectations, arm muscle strength did not have a statistically significant direct effect on shooting accuracy. While stronger muscles may aid in force generation, precision tasks like Petanque shooting rely more on control and strategic execution than brute strength (Bauer et al., 2022; Sinka et al., 2024). This result challenges general assumptions from other throwing sports, such as javelin or shot put, highlighting the importance of sport-specific analyses rather than extrapolating findings from unrelated disciplines (Pratama et al., 2024; Helmi et al., 2024).

These findings have practical implications for coaches and athletes. Training programs should prioritize wrist mobility exercises and cognitive drills to enhance decision-making under pressure. Techniques may include dynamic stretching, proprioceptive wrist exercises, scenario-based problem-solving training, and reflective strategic planning. Such integrative approaches can optimize shooting performance more effectively than focusing primarily on muscle strength.

Despite these contributions, the study has limitations. The small sample size and purposive sampling limit generalizability beyond female Petanque athletes in West Sumatra. The cross-sectional design restricts causal interpretation, and only three variables were examined, omitting factors such as balance, hand-eye coordination, motivation, or anxiety. Measurement of problem-solving through self-report questionnaires may not fully capture real-time cognitive adaptability, and environmental factors like terrain or weather during testing were uncontrolled, potentially introducing variability.

Future research should expand variable scope to include other physical and cognitive attributes, employ larger and more diverse samples, and compare performance across genders, regions, and skill levels. Longitudinal or experimental designs would provide stronger evidence of causal relationships, and technology such as motion capture or eye-tracking could yield more precise biomechanical and cognitive data. Mixed-methods studies combining quantitative and qualitative analyses may offer deeper insight into athlete decision-making processes.

In conclusion, this study demonstrates that wrist flexibility and problem-solving ability play critical roles in Petanque shooting accuracy, while arm muscle strength is less influential. These findings underscore the need for holistic training approaches that integrate both physical and cognitive conditioning. Addressing these limitations and building on the current results can further advance scientific understanding and improve practical training methods in precision-based sports (Zulbahri et al., 2024; Irawan et al., 2024; Pelana et al., 2021).

Conclusions

This study concludes that wrist flexibility and problem-solving ability significantly influence shooting accuracy in female Petanque athletes, while arm muscle strength shows a positive but non-significant effect, indicating that precision-based performance relies more on fine motor control and cognitive decision-making than brute strength. Flexible wrists improve control over release angles and shot

direction, and strong problem-solving skills enable effective strategic adaptation during dynamic gameplay, suggesting that training programs should prioritize wrist mobility exercises and cognitive drills over muscular power. The study is limited by a small sample size, cross-sectional design, and focus on only three variables, restricting generalizability and causal inference. Future research should examine additional physical and psychological factors, include larger and more diverse populations, and employ longitudinal or experimental designs to strengthen evidence. Overall, these findings provide a foundation for holistic, evidence-based training strategies and contribute to understanding multidimensional factors in precision-based sports.

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