

Core Endurance and Dynamic Balance in Bali Surfers: A Cross-Sectional Study

I Gede Totti Deva Pradnyana^{1*}, Putu Yudi Pramana Putra², Indah Pramita³,
Gede Parta Kinandana⁴

¹Undergraduate and Professional Physiotherapy Program, Faculty of Medicine, Udayana University

^{2,3,4}Department of Physiotherapy, Faculty of Medicine, Udayana University

*Correspondence author at: Jl. Raya Kampus Unud, Jimbaran, South Kuta, Badung Regency, Bali 80361, Indonesia

E-mail address: tottideva8@gmail.com

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Abstract

Introduction: Surfing is an extreme sport that requires balance, strength, and core muscle endurance to maintain body stability while maneuvering on a surfboard. The core muscles are crucial in supporting dynamic balance, making good core endurance essential for surfers to sustain their position and reduce the risk of injury. This study aims to analyze the relationship between core muscle endurance and dynamic balance in surfing athletes in Bali.

Methods: This study employed a cross-sectional design with an analytical approach. The sample was selected using a consecutive sampling technique (non-probability sampling), consisting of 60 surfing athletes aged 18–35 with a minimum of one year of experience in Bali. Core muscle endurance was measured using the plank test, while dynamic balance was assessed using the Y Balance Test, which has been validated for reliability. Data were analyzed using the Spearman-Rho test.

Results: The Spearman-Rho test showed a p-value of 0.000 ($p < 0.05$) with a correlation coefficient of -0.594, indicating a negative relationship between core muscle endurance and dynamic balance. Other factors like surfing techniques and muscle load distribution may also influence balance.

Conclusion: Higher core muscle endurance does not necessarily correlate positively with dynamic balance. Further studies are needed to explore additional factors influencing dynamic balance in surfing athletes.

Keywords: Core muscle endurance, dynamic balance, surfing, athlete

Introduction

Surfing is an extreme sport that demands exceptional physical performance. It heavily relies on dynamic balance, which is influenced by core muscle endurance in maintaining body stability and responding to positional changes on the surfboard.¹ Good core muscle endurance helps surfers control body movements, reduce excessive compensation in the extremities, and enhance biomechanical efficiency during maneuvers. The core muscles are crucial in various sports, stabilizing and transferring energy.^{2,3} A strong core allows surfers to maintain a stable posture, optimize movement coordination, and reduce the risk of falling during maneuvers.⁴

The core, also known as the lumbopelvic-hip complex, is a three-dimensional space bordered by the diaphragm at the top, the abdominal and oblique muscles at the front and sides, the paraspinal and gluteal muscles at the back, and the pelvic floor and hip girdle at the bottom. All these components function to stabilize the trunk and spine.⁵

Balance is fundamental to maintaining body posture in various static and dynamic positions. Static balance refers to the ability to maintain a stationary position, while dynamic balance is the ability to maintain stability while in motion.⁶ In surfing, dynamic balance depends on the body's ability to control its center of mass over an unstable base of support, which is influenced by neuromuscular coordination and core muscle strength. Surfers must maintain their position on a continuously moving surfboard, affected by ocean waves.⁷

Several studies have identified that injuries in surfing frequently occur, primarily due to contact with the surfboard.⁸ Poor dynamic balance increases the risk of injuries, especially in the lower extremities and trunk, due to improper weight distribution and uncontrolled movement compensation. A study conducted by Pinho Monteiro in 2020, titled "*Injury Patterns in Competitive and Recreational Surfing: A Systematic Review*," found that the most common injuries in surfing affect the skin, ligaments/joints, and muscles/tendons. The study reported that 39% of competitive surfers experienced skin injuries due to direct contact with the surfboard.⁹

Additionally, research by Liisa Airaksinen in 2013, titled "*The Role of Core Stability in Surfing, According to a Delphi Panel*," emphasized the importance of core stability in surfing for enhancing stabilization, preventing injuries, improving extremity performance efficiency, and refining surfers' balance.¹⁰ However, this study focused more on stability than core muscle endurance, explicitly highlighting the need to explore the relationship between core endurance and dynamic balance. Core stability also plays a crucial role in distributing force from the core to the extremities and reducing injury risk during major maneuvers on waves.¹¹

Bali is one of the world's premier surfing destinations, attracting thousands of local and international surfers training at renowned beaches such as Uluwatu, Canggu, and Kuta. However, no studies have specifically evaluated core muscle endurance and dynamic balance among surfing athletes in Bali. Therefore, this study aims to address this research gap by assessing how core muscle endurance influences dynamic balance in surfing athletes in Bali.

This study aims to analyze the relationship between core muscle endurance and dynamic balance in surfing athletes in Bali. The research hypothesis posits a significant correlation between core muscle endurance and dynamic balance in these athletes. Theoretically, higher core endurance is expected to correlate positively with better dynamic balance. However, if a negative correlation is found, it may be attributed to factors such as excessive muscle tension or inefficient muscle activation patterns.

Methods

This study is an analytical observational study with a cross-sectional design chosen because it allows for the analysis of the relationship between core muscle endurance as the independent variable and dynamic balance as the dependent variable at a single point in time without intervention. This design is more appropriate than a longitudinal approach, as the study does not aim to observe changes in variables over time but rather to analyze the relationship between variables at a specific moment. Additionally, potential confounding variables such as surfing experience and history of other physical training were recorded and analyzed as possible factors influencing dynamic balance.

This study was conducted between February and December 2024 at Kuta Beach, Kuta District, Badung Regency, Bali. This location was selected as one of Bali's main surfing hubs, with many active surfers and consistent wave characteristics, allowing for recruiting participants who meet the study criteria. Participant recruitment occurred from February to May 2024, data collection was carried out from June to August 2024, and data analysis was conducted from September to December 2024. External factors such as weather conditions and the tourist season in Bali were considered in planning the study period, as holiday seasons may affect the availability of surfers and environmental conditions that could influence athlete performance during measurements.

The study sample consisted of 60 male surfers aged 18 to 32 years. This age range was selected to represent the optimal phase of physical and athletic performance development, which can influence core muscle endurance and dynamic balance. Participants had to have been practicing surfing for at least three months, a duration deemed sufficient to develop core muscle endurance relevant to this study. They also needed to be able to communicate effectively, cooperate, and voluntarily participate after signing an informed consent form. Exclusion criteria included surfers with upper and/or lower extremity injuries and those with a history of asthma, as these conditions could limit participants' ability to maintain posture during the plank test or perform the Y Balance Test. The exclusion criteria did not include other respiratory diseases due to their varying effects on physical performance.

Sampling was conducted using a non-probability sampling method with a consecutive sampling technique, in which every surfer who met the criteria and agreed to participate was included sequentially until the sample size was met. However, this method may introduce recruitment bias, as participants will likely come from specific surfing communities or only those actively surfing at Kuta Beach. Participants were recruited through surfing communities in Bali, social media, and notice boards at surfing training centers. Before participating in the study, subjects underwent a brief interview to ensure they met the inclusion and exclusion criteria.

The study variables included core muscle endurance as the independent variable, measured by the duration of the plank test, and dynamic balance as the dependent variable, which were assessed using the composite Y Balance Test based on the average maximal reach in three movement directions. The plank test was selected because it is a validated method for evaluating core muscle endurance and has high reliability compared to other methods, such as the prone bridge endurance test. Additionally, supplementary variables such as age, surfing experience, and history of physical training were recorded for analysis as potential factors influencing dynamic balance. The Y Balance Test was conducted on both legs to obtain more comprehensive balance data, rather than just the dominant leg. Based on previous studies, this method has high reliability, with an ICC > 0.80.

To minimize bias, the plank test and Y Balance Test were conducted by trained researchers to ensure measurement consistency. A warm-up session was conducted before testing to reduce variability due to fatigue or inadequate physical preparation. Measurement instructions were provided verbally and in writing to ensure all participants understood the procedures. The study also implemented blinding for the examiners, preventing them from knowing previous measurement results to minimize potential subjectivity bias in recording results. Furthermore, a preliminary pilot test was conducted before the main study to ensure consistency in procedures and the reliability of the measurement instruments.

The sample size for this study was determined to be 60 participants, based on power analysis calculations with a 95% confidence level and 80% power, using an estimated correlation derived from previous studies investigating similar relationships. Additional recruitment was carried out to maintain the required sample size if any participants withdrew from the study.

Data analysis included univariate and bivariate analyses. Univariate analysis was performed to describe subject characteristics, while bivariate analysis utilized Spearman's rho test, as normality tests indicated that the data were not normally distributed. Normality testing was conducted using the Shapiro-Wilk test. The correlation was considered significant if $p < 0.05$. If additional variables such as surfing experience or age were found to contribute to dynamic balance, supplementary regression analysis was performed to evaluate the influence of these factors on the primary relationship being studied. In cases of missing data, the complete case analysis method was employed, in which only complete datasets were included in the analysis.

This study received approval from the Chairman of the Indonesian Surfing Association Bali, as indicated by letter number B/1047/UN14.2.2.V.7/PT.01.04/2024, and was reviewed and approved by the Ethics Committee of the Faculty of Medicine, Udayana University, under approval number 1265/UN14.2.2.VII.14/LT/2024 and protocol number 2024.01.1.0552. Participants were provided comprehensive information about the study and signed informed consent forms before participating according to ethical research principles.

Results

This study began with the sample selection based on the predetermined inclusion and exclusion criteria. The following research flow diagram provides a systematic overview of the population size, subject selection, group allocation, and the number of samples that completed the study. These steps aim to ensure the accuracy and validity of the data obtained.

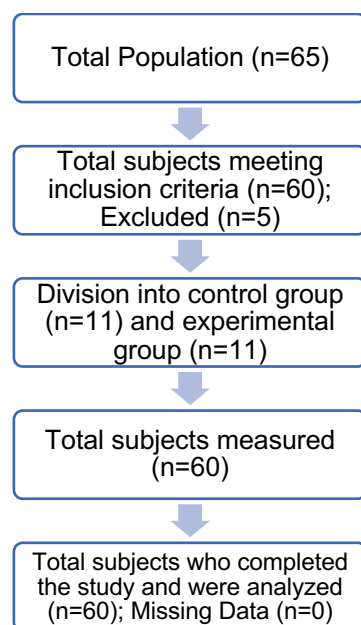


Figure 1. Flow Diagram

The study sample consisted of surfers or surfing athletes in Kuta District, aged between 18 and 32. Based on the formula used to determine the sample size, 60 individuals met the inclusion and exclusion criteria. The sampling method employed was non-probability sampling using a consecutive sampling technique. The sample characteristics based on age distribution are presented in **Table 1**.

Table 1. Age Distribution of the Study Sample

Age (years)	Frequency	Percentage (%)
18-22	22	37
23-27	20	33
28-32	18	30

Based on Table 1, the mean age of the sample was 24.37 years, with a standard deviation of 4.434. The most common age range was 18–22 years (37%), while the least common was 28–32 years (30%). The distribution of core muscle endurance is presented in Table 2.

Table 2. Core Muscle Endurance Distribution in the Study Sample

Core Muscle Endurance	Frequency	Percentage (%)
Poor	16	26.7
Below Average	14	23.3
Average	26	43.3
Excellent	4	6.7
Total	60	100

As shown in Table 2, most of the sample had an Average core muscle endurance level (26 individuals, 43.3%), followed by Poor (16 individuals, 26.7%), Below Average (14 individuals, 23.3%), and Excellent (4 individuals, 6.7%). The distribution of dynamic balance is displayed in Table 3.

Table 3. Dynamic Balance Distribution in the Study Sample

Dynamic Balance	Frequency	Percentage (%)
Balanced	44	73.3
Unbalanced	16	26.7
Total	60	100

Table 3 shows that most participants were categorized as Balanced (44 individuals, 73.3%), while the remaining 16 (26.7%) were classified as Unbalanced. Based on these data, a correlation analysis was conducted between core muscle endurance and dynamic balance, as shown in Table 4.

Table 4. Relationship Between Core Muscle Endurance and Dynamic Balance

Variables	r	p
Core Muscle Endurance	-0.594	0.000
Dynamic Balance		

Table 4 presents Spearman's rho correlation analysis results, showing a significance value of 0.000 ($p < 0.05$), indicating a significant relationship between core muscle endurance and dynamic balance among surfers in North Kuta District. The correlation coefficient of -0.594 suggests an inverse relationship with a strong correlation level (falling within the range of 0.51–0.75). This finding implies that the higher the core muscle endurance, the lower the dynamic balance observed among surfers in Bali. To further clarify this result, a theoretical analysis and additional references can be considered to understand the underlying mechanisms of this relationship.

Discussion

Characteristics of the Study Sample

This study involved participants aged 18 to 32 years, with the majority (37%) aged 18–22 years ($n = 22$), while the minor proportion (30%) was in the 28–32 age range ($n = 18$). All potential study participants were screened based on inclusion and exclusion criteria. Only male participants were included in the study due to differences in muscle control compared to females and higher testosterone levels, contributing to more significant muscle hypertrophy. This factor results in males generally having superior muscle performance compared to females.

Based on the study findings, core muscle endurance measured using the plank exercise was categorized as poor in 16 participants (26.7%), below average in 14 participants (23.3%), average in 26 participants (43.3%), and excellent in 4 participants (6.7%). Meanwhile, dynamic balance, assessed using the Y Balance Test, showed that 44 participants (73.3%) were categorized as balanced, while 16 participants (26.7%) were classified as unbalanced. The Y Balance Test was chosen due to its high reliability, with interrater and test-retest measures showing an acceptable level of measurement error.

Based on these measurements, it can be concluded that surfers training in Bali generally have average core muscle endurance and good dynamic balance. This indicates a lower risk of injury, as good dynamic balance reduces the likelihood of losing stability while surfing. However, further analysis is needed to explore the specific mechanisms linking core muscle endurance with dynamic balance in surfing, as well as potential moderating or mediating variables that may influence this relationship.

The study also examined the duration of participants' involvement in surfing. Training duration may impact coordination and balance, crucial for executing maneuvers while standing on a surfboard and adapting to different wave conditions. Therefore, effective coordination between core muscle endurance and dynamic balance is essential for surfers to maintain optimal performance.

The Relationship Between Core Muscle Endurance and Dynamic Balance

The relationship between core muscle endurance and dynamic balance in surfing in Bali was analyzed using the non-parametric Spearman's rho test. As shown in Table 4, the p-value obtained was 0.000, indicating statistical significance ($p < 0.05$), thereby supporting the research hypothesis. The correlation coefficient ($r = -0.594$) indicates a negative relationship, meaning that higher core muscle endurance is associated with lower dynamic balance among surfers in Bali.

This finding may be explained by several factors, including potential muscle fatigue from prolonged plank exercises, the lack of specificity of the plank exercise in replicating the balance demands of surfing, and possible biomechanical compensations that lead to an imbalance in weight distribution during the balance test.

These results align with a study by Nugraha et al. (2016), highlighting that dynamic balance refers to the body's ability to control its center of mass or center of gravity relative to the support base.¹² Maintaining balance requires integrating sensory systems, including visual, vestibular, and somatosensory inputs, which provide information to the central nervous system for postural adaptation.¹³

When linked to an individual's center of gravity, core muscle endurance can be considered a factor in stabilizing mass distribution, preventing surfers from quickly falling off their surfboards. Furthermore, the line of gravity and base of support work synergistically with the center of gravity. Proper mass distribution allows for better control of the line of gravity, optimizing balance maintenance.¹⁴

However, the negative correlation observed in this study contrasts with the findings by Putri et al. (2022) and Ferriyani et al. (2021), who reported a positive relationship between core muscle endurance and dynamic balance. This discrepancy may be due to differences in the sport, as surfing requires a more complex balance adaptation than land-based sports like badminton.¹⁵ Future studies comparing the effects of core endurance training across various water sports may provide a deeper understanding of this phenomenon.¹⁶

This study has several limitations. Core muscle endurance was measured using the plank exercise, which may not fully represent core muscle function in surfing, as the sport requires more complex dynamic postural control. Additionally, the lack of a control variable to assess muscle fatigue before and after testing may have influenced the results, as fatigue could impact dynamic balance performance. The Y Balance Test may also not entirely reflect the dynamic conditions of surfing on water. Moreover, fatigue induced by the plank exercise could have affected core

endurance measurements. Biomechanical factors, such as weight distribution or stance on the surfboard, were not analyzed further despite their potential importance in understanding the relationship between core endurance and dynamic balance.

The implications of these findings for surfers in Bali should be interpreted cautiously, as the aforementioned factors could lead to either an overestimation or underestimation of the effects observed in this study. The findings may apply to surfers with specific experience levels but may not be generalizable to all surfers, particularly those in locations with different wave characteristics. Since Bali's wave conditions may have influenced the results, additional research in other places is needed to confirm these findings.

For future research, it is recommended to employ balance measurement methods more specific to surfing conditions, such as testing in aquatic environments or using balance sensors to assess postural adaptations more accurately. Additionally, longitudinal studies examining the long-term effects of core endurance training on surfers' dynamic balance may provide a more comprehensive understanding of the benefits of such training. Other factors, such as surfing experience and core endurance training techniques, could also be explored as potential moderators of the relationship between core muscle endurance and dynamic balance.

Conclusion

This study aimed to analyze the relationship between core muscle endurance and dynamic balance in surfers in Bali. The analysis results indicate a significant negative correlation between the two variables ($p = 0.000$, $r = -0.594$), meaning that higher core muscle endurance is associated with lower dynamic balance performance. These findings suggest that while core muscle endurance plays a crucial role in postural stability, the negative relationship observed in this study may be attributed to biomechanical factors, measurement methods, or muscle fatigue during the plank endurance test. Additionally, dynamic balance in surfers is likely influenced more by surfing experience, sensorimotor coordination, and the ability to adapt to varying wave conditions.

The limitations of this study include its specific study location and measurement methods that may not fully represent real-world surfing conditions. Therefore, further research is needed to directly assess these factors and explore balance assessment methods that better reflect surfing activities, such as balance simulations on a surfboard or using force plates to analyze weight distribution. Future studies should also involve surfers with different experience levels or from locations with varying wave characteristics to determine whether this relationship remains consistent. Moreover, incorporating variables such as surfing experience, maneuvering techniques, or specific balance training could provide deeper insights into the key factors influencing dynamic balance in surfers.

Author Contribution

I Gede Totti Deva Pradnyana: Conceptualization, methodology, data collection, data analysis, and manuscript drafting.

Putu Yudi Pramana Putra: Supervision, guidance on research design, and critical review of the manuscript.

Indah Pramita: Supervision, validation, and manuscript editing.

Gede Parta Kinandana: Supervision, methodological consultation, and final manuscript review.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest related to this study.

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Ethics Statement

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Research Ethics Committee of the Faculty of Medicine, Universitas Udayana (Approval No. 1265/UN14.2.2.VII.14/LT/2024). All participants provided informed consent prior to data collection.

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