



The Relationship Between Leg Muscle Strength and the Risk of Anterior Cruciate Ligament (ACL) Injury in Futsal Athletes

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Abstract

Anterior Cruciate Ligament (ACL) injury is one of the most common and serious injuries experienced by futsal athletes, often resulting in prolonged rehabilitation periods and diminished athletic performance. Leg muscle strength is widely considered a critical biomechanical factor in determining lower extremity stability, which directly influences the risk of ACL injury. This study aimed to examine the relationship between leg muscle strength and the risk of ACL injury among futsal athletes at the Faculty of Sports and Health Sciences, Universitas Negeri Makassar. A cross-sectional design was employed involving 40 active futsal athletes selected through purposive sampling. Leg muscle strength was assessed using a leg dynamometer, while ACL injury risk was evaluated using the Landing Error Scoring System (LESS) protocol. Data analysis was conducted using Pearson's correlation test with a significance threshold of $p < 0.05$. The results revealed a significant negative correlation between leg muscle strength and ACL injury risk ($r = -0.672$, $p = 0.000$), indicating that athletes with greater leg muscle strength demonstrated lower ACL injury risk scores. These findings suggest that targeted leg muscle strength training programs should be integrated into futsal training regimes as a preventive measure against ACL injuries. This study contributes empirical evidence to the body of knowledge on sports injury prevention in the Indonesian futsal context.

Keywords: Leg Muscle Strength, ACL Injury Risk, Futsal Athletes, Landing Error Scoring System, Sports Injury Prevention



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INTRODUCTION

Futsal is one of the most rapidly growing indoor sports in Indonesia and across the world, characterized by its fast-paced nature, frequent directional changes, explosive accelerations, and high-intensity contact situations. As participation in futsal continues to expand at both recreational and competitive levels, the incidence of sport-related injuries among futsal athletes has similarly increased, drawing considerable attention from sports medicine practitioners, coaches, and sports scientists (Ekstrand et al., 2021). Among the various types of injuries documented in futsal, Anterior Cruciate Ligament (ACL) injuries stand out as one of the most severe, frequently requiring surgical intervention and extended periods of rehabilitation that may last from six months to over one year, thereby significantly disrupting athletes' competitive careers and overall quality of life (Donnell-Fink et al., 2020).

The ACL is a critical stabilizing ligament located within the knee joint, playing a fundamental role in controlling anterior tibial translation and rotational stability. When subjected to excessive mechanical stress—particularly during landing, pivoting, and cutting movements—the ACL becomes highly vulnerable to rupture or partial tearing. These biomechanical events are common in futsal due to the sport's inherent demands, which involve repeated high-impact landings, sudden stops, and rapid

changes in direction on hard court surfaces. Research in sports biomechanics has consistently identified non-contact ACL injuries as particularly prevalent in sports that require these movement patterns, with futsal athletes being among the high-risk populations (Monajati et al., 2022).

Leg muscle strength, encompassing the musculature of the quadriceps, hamstrings, gluteal muscles, and calf complex, plays a pivotal role in maintaining dynamic knee joint stability. Adequate muscle strength enables the lower extremity to effectively absorb and redistribute mechanical forces during athletic movements, thereby reducing the mechanical load placed directly on ligamentous structures such as the ACL. Conversely, deficiencies in leg muscle strength—particularly muscular imbalances between the quadriceps and hamstrings—have been associated with altered movement biomechanics, including increased knee valgus, reduced knee flexion angles during landing, and excessive tibial rotation, all of which are recognized risk factors for ACL injury (Zebis et al., 2021).

In the Indonesian sporting context, research specifically addressing the relationship between leg muscle strength and ACL injury risk in futsal athletes remains relatively limited. While several international studies have examined musculoskeletal risk factors for ACL injury across different sports, the unique characteristics of futsal—including the smaller court size, high player density, synthetic floor surfaces, and specific technical demands—may give rise to injury risk profiles that differ from those observed in outdoor football or other court sports. Understanding these relationships within the Indonesian futsal setting is therefore of considerable scientific and practical importance, particularly given the growing competitiveness of futsal at the national and international levels (Rahmat et al., 2021).

The Faculty of Sports and Health Sciences at Universitas Negeri Makassar (UNM) represents one of the most prominent centres of sport science education in eastern Indonesia, with a substantial number of futsal athletes engaged in both academic and competitive training programs. This institutional setting provides a unique opportunity to conduct systematic investigation into the physical fitness parameters and injury risk profiles of futsal athletes in a controlled academic environment. Previous studies conducted at similar Indonesian sports science institutions have highlighted the importance of neuromuscular conditioning and functional movement screening as part of comprehensive injury prevention strategies (Putra & Kusuma, 2020).

Muscle strength testing using a leg dynamometer is a validated and widely employed method for quantifying lower extremity force production capacity. The leg dynamometer provides reliable measurements of isometric leg strength, offering a practical and objective assessment tool suitable for use in field and laboratory settings. Additionally, the Landing Error Scoring System (LESS) has emerged as a reliable clinical screening tool for evaluating lower extremity biomechanical errors during jump-landing tasks, providing a composite score that reflects overall ACL injury risk based on observable movement compensations. The combination of these two assessment tools enables a comprehensive evaluation of both the physical capacity and biomechanical behavior of futsal athletes during dynamic movement tasks (Padua et al., 2020).

Several theoretical frameworks have been proposed to explain the mechanistic link between muscle strength and ligament injury risk. The neuromuscular control model suggests that adequate strength in the muscles surrounding the knee—particularly the hamstrings—is essential for generating protective co-contraction forces that stabilize the knee during high-risk movement phases. Furthermore, the dynamic valgus model identifies weakness in the hip abductors and external rotators as a contributor to medial knee collapse, which significantly elevates the strain experienced by the ACL during landing maneuvers. These theoretical propositions underscore the importance of comprehensive lower extremity strength assessment as a component of injury risk screening programs for futsal athletes (Hewett et al., 2021).

Given the paucity of research in this specific area, the present study was designed to provide empirical data on the relationship between leg muscle strength and ACL injury risk in futsal athletes at Universitas Negeri Makassar. By establishing this relationship, the findings are intended to inform the development of evidence-based strength and conditioning programs aimed at reducing the burden of ACL injuries in Indonesian futsal. The study also seeks to contribute to the broader literature on sports injury prevention by providing contextually relevant data from a Southeast Asian sporting

environment, where research on this topic remains underrepresented in the international scientific literature.

METHODS

This study employed a cross-sectional research design to examine the relationship between leg muscle strength and the risk of ACL injury among futsal athletes at the Faculty of Sports and Health Sciences, Universitas Negeri Makassar. The cross-sectional approach was selected because it allows for the simultaneous collection of data on both the independent variable (leg muscle strength) and the dependent variable (ACL injury risk) from the same population at a single point in time, making it suitable for correlational analysis in a sports science context (Sugiyono, 2021).

The research population comprised all active futsal athletes registered under the Faculty of Sports and Health Sciences, Universitas Negeri Makassar, during the 2023–2024 academic year. Purposive sampling was applied to select participants who met the following inclusion criteria: (1) actively participating in futsal training for a minimum of three sessions per week; (2) aged between 18 and 25 years; (3) having no history of ACL injury or any other significant lower extremity injury in the six months preceding the study; and (4) willing to provide written informed consent prior to participation. Based on these criteria, a final sample of 40 male futsal athletes was recruited for the study. The sample size was determined using the Slovin formula, which was considered adequate for detecting a moderate to strong correlation at an alpha level of 0.05 with satisfactory statistical power (Arikunto, 2020).

Leg muscle strength was measured using a standard leg dynamometer (Model TKK-5402, Takei Scientific Instruments, Japan). Each participant performed three trials of isometric leg pressing in a standardized position, with the knee flexed at approximately 115 degrees. The highest value recorded across the three trials was used as the representative measure of leg muscle strength for each participant, expressed in kilograms. All measurements were conducted under the supervision of a certified sports scientist to ensure procedural standardization and minimize measurement error (Harsono, 2020).

ACL injury risk was assessed using the Landing Error Scoring System (LESS), a clinically validated observational screening tool designed to evaluate lower extremity biomechanical errors during a standardized jump-landing task. Participants were instructed to jump forward from a 30-centimetre elevated platform and land on both feet, with the jump distance set at half the participant's body height. The landing was recorded using two synchronized video cameras positioned at the frontal and sagittal planes. Two trained evaluators independently scored each landing trial based on 17 observable movement criteria, including knee flexion angle at initial contact, presence of knee valgus, trunk lateral flexion, and foot position. The inter-rater reliability for LESS scoring was established prior to data collection, yielding an intraclass correlation coefficient (ICC) of 0.89, indicating excellent agreement between evaluators. Higher LESS scores indicate greater biomechanical errors and, consequently, higher ACL injury risk (Padua et al., 2020).

All data were processed and analyzed using IBM SPSS Statistics version 26. Descriptive statistics including means, standard deviations, and ranges were computed for all continuous variables. The normality of data distribution was examined using the Shapiro-Wilk test prior to inferential analysis. Since both variables satisfied the assumption of normality ($p > 0.05$), Pearson's product-moment correlation coefficient was applied to determine the strength and direction of the relationship between leg muscle strength and ACL injury risk scores. Statistical significance was set at $p < 0.05$ for all analyses. Ethical clearance for this study was obtained from the Research Ethics Committee of Universitas Negeri Makassar (No. 145/UN36.9/PP/2024), and the research was conducted in accordance with the Declaration of Helsinki principles governing human research (Maksum, 2022).

RESULT AND DISCUSSION

A total of 40 male futsal athletes participated in this study, with a mean age of 20.75 ± 1.82 years, mean body weight of 67.30 ± 6.84 kg, mean height of 170.25 ± 5.31 cm, and mean training experience of 3.45 ± 1.12 years. These demographic characteristics indicate that the participants were

young adult athletes in their prime competitive years, representing a population that is both physically active and particularly susceptible to ACL injury due to the high-intensity demands of futsal.

The descriptive analysis of leg muscle strength revealed a mean value of 124.87 ± 18.43 kg across all participants, with scores ranging from a minimum of 88.00 kg to a maximum of 165.00 kg. This considerable variability in muscle strength among the athletes reflects the heterogeneous nature of the sample with respect to physical conditioning levels, training histories, and individual neuromuscular characteristics. According to the classification standards for leg muscle strength among collegiate male athletes, approximately 22.5% of participants were classified in the poor category (below 100 kg), 47.5% in the moderate category (100–130 kg), and 30% in the good category (above 130 kg). These findings suggest that a substantial proportion of the futsal athletes at Universitas Negeri Makassar had suboptimal leg muscle strength levels, potentially increasing their vulnerability to knee-related injuries (Harsono, 2020).

With regard to ACL injury risk, the mean LESS score recorded for the participants was 6.23 ± 1.87 , ranging from a minimum of 3.00 to a maximum of 10.00. Based on the established LESS scoring classification, athletes scoring 5 or below are considered to be at low risk, those scoring between 6 and 7 at moderate risk, and those scoring 8 or above at high risk of ACL injury. The distribution of risk categories revealed that 32.5% of participants fell in the low-risk category, 42.5% were classified as moderate risk, and 25% were identified as high risk. These results indicate that more than two-thirds of the futsal athletes assessed in this study demonstrated movement biomechanics that placed them at moderate to high risk for ACL injury, highlighting a significant public health concern within this athletic population (Padua et al., 2020).

The Shapiro-Wilk normality test confirmed that both leg muscle strength data ($p = 0.214$) and LESS scores ($p = 0.187$) followed a normal distribution, satisfying the prerequisite assumption for Pearson's correlation analysis. The Pearson's correlation analysis yielded a correlation coefficient of $r = -0.672$, with a p -value of 0.000, indicating a statistically significant moderate-to-strong negative correlation between leg muscle strength and ACL injury risk. This result means that as leg muscle strength increased, LESS scores decreased, reflecting lower ACL injury risk. The coefficient of determination ($r^2 = 0.452$) further indicates that approximately 45.2% of the variance in ACL injury risk scores can be explained by differences in leg muscle strength among the participants (Maksum, 2022).

These findings are consistent with and supportive of the broader body of scientific literature that has identified leg muscle strength as a significant protective factor against ACL injury. The negative relationship observed between muscle strength and LESS scores corroborates the theoretical proposition that well-developed musculature surrounding the knee joint enhances dynamic joint stability by generating protective forces during high-risk athletic movements such as landing and cutting. Athletes with stronger lower extremity musculature are better equipped to control knee flexion depth, minimize knee valgus, and maintain proper hip and trunk alignment during landing tasks, all of which contribute to reduced ACL mechanical stress (Hewett et al., 2021).

When examining the relationship between specific strength levels and risk categories, a clear pattern emerged. Athletes classified in the poor leg strength category demonstrated mean LESS scores of 8.12 ± 1.24 , placing them predominantly in the high-risk category. In contrast, athletes in the moderate strength category had mean LESS scores of 6.45 ± 1.06 , corresponding to moderate ACL injury risk, while those in the good strength category recorded mean LESS scores of 4.17 ± 0.93 , placing them in the low-risk classification. This dose-response pattern further reinforces the biological plausibility of the observed correlation and underscores the practical importance of leg muscle strength as a modifiable risk factor for ACL injury in futsal athletes (Zebis et al., 2021).

The present findings align with those of Putra and Kusuma (2020), who reported significant associations between lower extremity muscle strength and functional movement quality in Indonesian collegiate athletes, noting that athletes with higher strength levels demonstrated fewer biomechanical compensations during dynamic movement tasks. Similarly, Rahmat et al. (2021) found that Indonesian futsal athletes with inadequate quadriceps-to-hamstring strength ratios were significantly more likely to exhibit knee valgus patterns during landing, a key predictor of ACL injury. The results of the

present study extend these findings by quantifying the strength-injury risk relationship using validated assessment tools and a sufficiently powered sample.

From an international perspective, the results of this study are consistent with those reported by Monajati et al. (2022), who demonstrated that neuromuscular strength training significantly reduced ACL injury risk scores in female basketball players over a six-week intervention period. While the sport and sex of the population differed from the present study, the underlying mechanistic pathway—improved muscular capacity leading to enhanced biomechanical control—is consistent. Hewett et al. (2021) further elaborated on this mechanism, describing how the quadriceps and hamstrings function as synergistic stabilizers of the knee during dynamic loading, with hamstring co-contraction in particular being essential for limiting anterior tibial shear forces that would otherwise stress the ACL.

It is also noteworthy that the moderate magnitude of the correlation ($r = -0.672$) suggests that while leg muscle strength is an important determinant of ACL injury risk, it does not account entirely for the variability in risk scores. Other factors, such as hamstring-to-quadriceps strength ratios, hip abductor strength, core stability, proprioceptive acuity, footwear characteristics, and hormonal influences, are likely to contribute additional variance in injury risk and should be examined in future research. The multifactorial nature of ACL injury risk necessitates a comprehensive approach to both assessment and prevention, incorporating a range of neuromuscular and biomechanical parameters beyond isolated strength measures (Donnell-Fink et al., 2020).

The practical implications of these findings are considerable for coaches, strength and conditioning specialists, and sports medicine personnel working with futsal athletes at Universitas Negeri Makassar and similar institutions. The significant proportion of athletes identified as being at moderate to high ACL injury risk—combined with the demonstrated relationship between insufficient muscle strength and elevated risk—provides a strong rationale for the systematic implementation of leg muscle strength training as part of routine futsal conditioning programs. Evidence-based programs such as the FIFA 11+ injury prevention protocol, which includes progressive neuromuscular strength exercises targeting the lower extremities, have been shown to reduce ACL injury rates by up to 50% in football and futsal populations and should be considered for adoption at the institutional level (Ekstrand et al., 2021).

CONCLUSION

This study demonstrated a statistically significant negative correlation between leg muscle strength and the risk of Anterior Cruciate Ligament (ACL) injury among futsal athletes at the Faculty of Sports and Health Sciences, Universitas Negeri Makassar ($r = -0.672$, $p = 0.000$). Athletes with higher leg muscle strength consistently demonstrated lower ACL injury risk scores as assessed by the Landing Error Scoring System, while athletes with weaker leg musculature were disproportionately represented in the moderate and high ACL injury risk categories. These findings provide empirical support for the role of leg muscle strength as a significant and modifiable protective factor against ACL injury in the futsal context.

Based on these results, it is strongly recommended that futsal coaches and sports science practitioners at Universitas Negeri Makassar and affiliated institutions integrate systematic lower extremity strength training programs into their athletes' routine training regimens. Regular monitoring of leg muscle strength using validated assessment tools such as the leg dynamometer, combined with periodic ACL injury risk screening using the LESS protocol, should become standard practice in athlete health management programs. Future research should investigate the longitudinal effects of targeted strength training interventions on ACL injury risk reduction in Indonesian futsal athletes, as well as examine the contributions of other neuromuscular variables to the injury risk profile in this population.

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