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Lower Limb Strength, Core Endurance, and Agility in Adolescent Male Futsal Players

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Abstract

Background: Futsal is a high-intensity intermittent sport requiring rapid acceleration, deceleration, and repeated changes of direction, making agility an essential performance component. Lower limb muscle strength and core muscle endurance are considered important physical factors associated with agility performance; however, evidence among adolescent futsal players remains limited.

Objective: To analyze the relationship between lower limb muscle strength and core muscle endurance with agility in adolescent male futsal players in Denpasar City.

Methods: This cross-sectional study involved 60 male futsal players aged 13–18 years recruited from futsal clubs in Denpasar City, Bali, Indonesia, between March and April 2026. Lower limb muscle strength was measured using a leg dynamometer, core muscle endurance using the McGill's Torso Endurance Test, and agility using the T-Test Agility. Data were analyzed using Spearman's rho correlation and multiple linear regression at $p < 0.05$.

Results: Lower limb muscle strength showed a significant negative correlation with agility ($r = -0.770$; $p < 0.001$), while core muscle endurance also demonstrated a significant negative correlation with agility ($r = -0.787$; $p < 0.001$). Regression analysis demonstrated that lower limb muscle strength ($B = -0.013$; $p = 0.024$) and core muscle endurance ($B = -0.021$; $p < 0.001$) were significantly associated with agility performance.

Conclusion: Lower limb muscle strength and core muscle endurance were significantly associated with agility in adolescent male futsal players.

Keywords
Adolescent; Athletic Performance; Futsal; Muscle Strength; Physical Endurance

Introduction

Futsal is a high-intensity intermittent sport characterized by rapid acceleration, deceleration, sprinting, and repeated multidirectional movements performed within a limited playing area. Compared with outdoor soccer, futsal is played on a smaller court with fewer players and shorter transition distances, resulting in a higher frequency of high-intensity actions and changes of direction during match play.[1,2] These physiological and biomechanical demands require players to possess optimal neuromuscular performance, particularly agility, to maintain competitive performance throughout the game.[3] Recent evidence indicates that futsal players perform frequent explosive movements involving acceleration, braking, cutting, and pivoting, with change-of-direction activities accounting for a substantial proportion of total match movements.[4] Consequently, agility is considered one of the most important biomotor components influencing technical execution, offensive and defensive transitions, and overall match effectiveness in futsal athletes.[5]

Agility is defined as the ability to rapidly change body position or direction in response to specific movement demands while maintaining postural control and movement efficiency.[6] From a biomechanical perspective, agility involves the integration of lower extremity force production, neuromuscular coordination, dynamic balance, and trunk stabilization.[7] During rapid directional changes, athletes must generate high propulsive and braking forces to control the center of mass efficiently while minimizing performance loss.[8] In futsal, insufficient agility may not only impair technical performance but also increase the risk of non-contact lower extremity injuries, particularly at the ankle and knee joints, due to inadequate neuromuscular control during deceleration and cutting maneuvers.[9] Therefore, understanding the physical factors associated with agility is important for both performance optimization and injury prevention in futsal athletes.

Lower limb muscle strength has been identified as one of the primary determinants of agility performance. Strong lower extremity muscles enable athletes to produce greater force during acceleration and deceleration phases, thereby facilitating more efficient directional changes.[10] Biomechanically, muscles such as the quadriceps, hamstrings, gluteus maximus, and gastrocnemius contribute synergistically to force absorption and propulsion during cutting and pivoting tasks.[11] Previous studies have demonstrated significant associations between lower limb strength and change-of-direction ability in team-sport athletes.[12,13] Furthermore, eccentric and concentric lower extremity strength are considered essential for controlling body momentum and maintaining movement efficiency during high-speed multidirectional tasks.[14] Nevertheless, most previous studies were conducted in soccer or mixed-sport populations, which may not fully represent the unique movement demands of futsal athletes.

In addition to lower limb muscle strength, core muscle endurance has also been proposed as an important component associated with agility performance. The core musculature functions as a central kinetic link that stabilizes the lumbopelvic region and facilitates force transfer between the upper and lower extremities during dynamic movement.[15] Adequate core endurance allows athletes to maintain trunk stability during repeated high-intensity activities, thereby improving movement efficiency and postural control.[16] The McGill's Torso Endurance Test, which evaluates flexor, extensor, and lateral trunk endurance, has frequently been used to assess trunk stabilization capacity in athletic populations.[17] Previous studies reported that athletes with better core endurance tend to demonstrate superior balance, movement control, and change-of-direction ability.[18,19] However, evidence regarding the association between core muscle endurance and agility remains inconsistent, particularly among adolescent futsal players.

The adolescent period represents a critical stage of neuromuscular and musculoskeletal development that may substantially influence physical performance. Biological maturation during adolescence is associated with increases in muscle mass, neural activation efficiency, coordination, and anaerobic performance capacity.[20] These developmental changes can affect lower limb strength, trunk stability, and agility performance in youth athletes.[21] Consequently, findings derived from adult or elite athletes cannot be directly generalized to adolescent futsal players because training adaptation, maturation status, and movement mechanics may differ substantially across age groups.[22] Despite the growing popularity of futsal among adolescents in Indonesia, evidence specifically examining the interaction between lower limb muscle strength, core muscle endurance, and agility in youth futsal players remains limited.[23]

Previous studies investigating agility performance have predominantly focused on soccer athletes or general athletic populations rather than futsal-specific athletes.[12,18] This represents an important research gap because futsal involves higher movement density, shorter recovery intervals, and more frequent directional transitions performed in confined spaces.[2,4] Moreover, previous research has rarely examined lower limb muscle strength and core muscle endurance simultaneously within the same analytical model among adolescent futsal players. Understanding the combined association of these physical components with agility may provide a more comprehensive perspective for designing evidence-based conditioning and injury-prevention programs in futsal athletes.

Therefore, this study aimed to analyze the relationship between lower limb muscle strength and core muscle endurance with agility in adolescent male futsal players in Denpasar City. Specifically, this study evaluated: (1) the relationship between lower limb muscle strength and agility, (2) the relationship between core muscle endurance and agility, and (3) the simultaneous association of both variables with agility performance. It was hypothesized that greater lower limb muscle strength and higher core muscle endurance would be significantly associated with better agility performance in adolescent futsal players.

Methods

This observational study used a correlational analytical approach with a cross-sectional design and was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline. The study was conducted between March and April 2026 at futsal training facilities in Denpasar City, Bali, Indonesia. The cross-sectional design was selected to evaluate the association between lower limb muscle strength, core muscle endurance, and agility at a single measurement period without intervention.

The target population consisted of adolescent futsal players actively participating in club-level training programs in Bali Province. The accessible population included male futsal players from Faith Futsal Academy and Futsal Club Muda Satria in Denpasar City. Participants were recruited using purposive sampling through direct coordination with coaches and club administrators. Although purposive sampling may increase the risk of selection bias, this approach was selected to ensure that participants met predefined athletic and training characteristics relevant to the study objectives.

Sample size calculation was performed using G*Power version 3.1 through an a priori power analysis for bivariate correlation testing. The parameters included a two-tailed hypothesis, $\alpha = 0.05$, statistical power $(1-\beta) = 0.80$, and an expected correlation coefficient of $r = 0.365$ derived from previous adolescent athletic research by Imai and Kaneoka.20 Based on these assumptions, the minimum required sample size was 56 participants. To compensate for potential participant exclusion and incomplete measurements, 68 participants were initially screened, resulting in 60 eligible participants included in the final analysis.

The inclusion criteria were: (1) male futsal players aged 13–18 years, (2) actively participating in futsal training at least twice weekly during the previous six months, (3) body mass index (BMI) within the normal Asian classification range (18.5–22.9 kg/m²), and (4) willingness to participate in all study procedures. The selected age range represented the adolescent developmental phase characterized by rapid neuromuscular adaptation, musculoskeletal growth, and substantial changes in physical performance capacity. Exclusion criteria included: (1) history of musculoskeletal injury during the previous six months, particularly anterior cruciate ligament injury, (2) congenital or chronic disease affecting physical performance, (3) participation in intensive strength training outside regular futsal training, and (4) inability to complete all measurements.

Prior to data collection, participants attended a familiarization session to ensure understanding of all testing procedures and reduce measurement variability associated with learning effects. All measurements were conducted by the same evaluator to minimize inter-rater variability. The evaluator followed standardized operating procedures for each assessment and was not informed of participants' previous measurement results during testing sessions to reduce observational bias.

Environmental and procedural standardization were implemented to improve measurement consistency. All assessments were conducted on the same indoor futsal court surface under relatively similar environmental conditions and during comparable training hours. Participants were instructed to avoid strenuous physical activity, caffeine intake, and additional exercise at least 24 hours before testing. Testing was preceded by a standardized 10–15 minute warm-up consisting of light jogging, dynamic stretching, and movement preparation exercises.

Anthropometric measurements included body weight and height assessment using a calibrated digital scale and stadiometer. BMI was calculated as body weight divided by height squared (kg/m²). Training frequency was obtained through direct participant interviews and verified with coaches when possible.

Lower limb muscle strength was measured using a leg dynamometer, which has demonstrated acceptable validity and reliability in lower extremity strength assessment.[24] Participants performed maximal isometric contraction in a semi-squat standing position while pulling the dynamometer handle vertically for approximately three seconds. Three trials were performed with one-minute rest intervals, and the highest value was recorded in kilograms as the final score.

Core muscle endurance was assessed using the McGill's Torso Endurance Test, which evaluates trunk flexor, extensor, and lateral musculature endurance.[17] The protocol consisted of the trunk flexor endurance test, trunk extensor endurance test, and side bridge endurance test. Each test was performed three times with adequate rest intervals to minimize fatigue accumulation. For the side bridge assessment, right and left side values were averaged. The total core endurance score was calculated by summing all test components and expressed in seconds.

Agility performance was measured using the T-Test Agility protocol due to its established reliability for multidirectional athletic performance assessment. Participants sprinted and changed direction along a T-shaped course consisting of forward sprinting, lateral shuffling, and backward running movements. The testing protocol used a standard cone arrangement with 9.14 m forward distance and 4.57 m lateral distance between cones. Two trials were completed with two-minute recovery intervals, and the best performance time in seconds was recorded for analysis.

Data quality control procedures were implemented throughout the study. All measuring instruments were calibrated prior to testing sessions. Measurement data were reviewed immediately after collection to identify incomplete or inconsistent recordings. No missing data were identified during the study. Outlier screening was conducted through descriptive inspection and diagnostic analysis. Although a wide range of lower limb muscle strength values was observed, all values remained within physiologically plausible limits and were therefore retained in the final analysis.

Descriptive statistics were used to summarize participant characteristics and study variables, including mean, standard deviation, minimum–maximum values, and frequency distributions where appropriate. Normality testing was performed using the Shapiro–Wilk test. Because the primary variables demonstrated non-normal distributions ($p < 0.05$), Spearman's rho correlation analysis was used to examine the relationships between lower limb muscle strength, core muscle endurance, and agility.

Multiple linear regression analysis was subsequently performed to evaluate the simultaneous association of independent variables with agility performance. Prior to regression analysis, assumptions of linearity, homoscedasticity, and multicollinearity were assessed through diagnostic procedures. No evidence of severe multicollinearity was identified between the independent variables based on variance inflation factor (VIF) and tolerance value assessment $. Standardized beta coefficients were additionally reported to improve interpretation of variable contribution within the regression model. Statistical significance was established at $p < 0.05$ using statistical analysis software.

Ethical clearance was not required for this study because all procedures involved non-invasive physical performance assessments conducted during routine athletic evaluation and did not involve medical intervention, biological sampling, or clinical treatment.[25] All participants and their parents or legal guardians received explanations regarding the study objectives, procedures, benefits, and potential risks before signing written informed consent. Participants were informed that participation was voluntary and that withdrawal from the study could occur at any time without consequence.

Results

The participant recruitment and selection process is illustrated in Figure 1 to provide a systematic overview of participant eligibility, exclusion, and final analytical inclusion according to observational reporting recommendations. The flowchart also demonstrates the completeness of data collection and analytical procedures performed throughout the study.

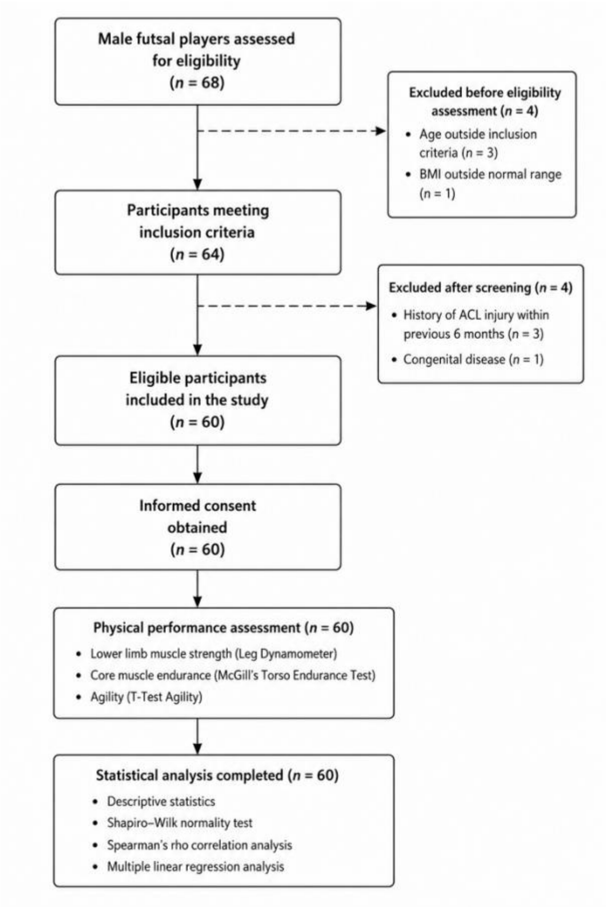

Figure 1. Participant Flow Diagram

A total of 60 adolescent male futsal players from two futsal clubs in Denpasar City completed all study procedures and were included in the final analysis. No missing measurements or participant withdrawals were identified during data collection or statistical analysis.

Participant demographic characteristics and primary study variables are presented in Table 1. The table provides an overview of age distribution, anthropometric characteristics, training frequency, lower limb muscle strength, core muscle endurance, and agility performance among study participants.

Table 1. Participant Characteristics and Main Study Variables

Variable	Mean ± SD	Minimum–Maximum	n (%)

Age (years)	15.22 ± 1.74	13–18	
13 years			15 (25.0)
14 years			8 (13.3)
15 years			9 (15.0)
16 years			13 (21.7)
17 years			7 (11.7)
18 years			8 (13.3)
Sex (male)			60 (100.0)
BMI (kg/m²)	20.73 ± 1.53	18.50–22.99	
Training frequency (times/week)	2.22 ± 0.42	2–3	
Lower limb muscle strength (kg)	61.15 ± 34.87	23–185	
Core muscle endurance total (s)	141.54 ± 42.88	69.86–267.47	
Flexor endurance (s)	57.41 ± 22.68	26.43–168.24	
Extensor endurance (s)	53.19 ± 20.30	21.00–111.00	
Side bridge endurance (s)	30.94 ± 12.01	9.00–67.00	
Agility (s)	11.79 ± 1.67	9.34–15.82	

The participants were predominantly mid-adolescent athletes with relatively homogeneous training frequency and normal BMI values. Lower limb muscle strength demonstrated substantial variability, ranging from 23 to 185 kg, suggesting considerable inter-individual differences in lower extremity force production capacity. Diagnostic evaluation and outlier screening indicated that these values remained within physiologically acceptable limits and therefore were retained in the final analysis.[26] Similar variability was also observed in core muscle endurance and agility performance, reflecting heterogeneous physical performance profiles among participants.

Normality testing using the Shapiro–Wilk test demonstrated non-normal distributions for the primary study variables ($p < 0.05$). Therefore, Spearman's rho correlation analysis was applied. Despite non-normality, regression residual diagnostics demonstrated acceptable linearity, homoscedasticity, and multicollinearity assumptions based on variance inflation factor (VIF) and tolerance value assessment[27], supporting the use of multiple linear regression analysis.

The relationships between lower limb muscle strength, core muscle endurance, and agility are presented in Table 2. The table summarizes correlation coefficients, confidence intervals, and regression coefficients to provide a comprehensive overview of the associations among study variables.

Table 2. Correlation and Regression Analysis of Variables Associated With Agility

Variable	r	Standardized Beta	p-value
Lower limb muscle strength vs agility	−0.770	−0.275	0.024
Core muscle endurance vs agility	−0.787	−0.541	<0.001

Both lower limb muscle strength and core muscle endurance demonstrated strong negative correlations with agility time. The negative correlation coefficients indicate that greater lower limb strength and higher core muscle endurance were associated with lower T-Test completion times, reflecting better agility performance. Core muscle endurance demonstrated a slightly stronger standardized beta coefficient compared with lower limb muscle strength, suggesting a relatively greater contribution within the regression model.

No evidence of severe multicollinearity was identified between the independent variables based on regression diagnostic evaluation.[28]

Discussion

This study demonstrated significant associations between lower limb muscle strength, core muscle endurance, and agility performance in adolescent male futsal players. Both independent variables showed strong negative correlations with agility time, indicating that participants with greater lower limb strength and better core muscle endurance tended to demonstrate superior agility performance, reflected by lower T-Test completion times. Simultaneous regression analysis further demonstrated that both variables remained significantly associated with agility after adjustment within the same analytical model. These findings suggest that lower extremity force production capacity and trunk stabilization endurance may represent important physical attributes related to multidirectional movement performance in adolescent futsal athletes.

The significant association between lower limb muscle strength and agility observed in this study is biomechanically plausible considering the movement demands of futsal. Agility performance requires rapid acceleration, deceleration, and directional transition while maintaining body control under high movement velocity. During change-of-direction tasks, the lower extremity musculature must absorb braking forces eccentrically and subsequently generate propulsive forces concentrically to redirect body momentum efficiently.[7,10] Muscles including the quadriceps, hamstrings, gluteus maximus, and gastrocnemius contribute synergistically to force generation, stabilization, and movement control during multidirectional athletic tasks.[11] Therefore, athletes with greater lower limb strength may demonstrate superior ability to control the center of mass and perform rapid directional changes with reduced movement inefficiency.

These findings are consistent with previous studies reporting significant associations between lower extremity strength and agility performance in team-sport athletes. Loturco et al.[14] demonstrated that change-of-direction ability is strongly influenced by neuromuscular performance and force production capacity of the lower limbs. Similarly, Hammami et al.[12] reported that improvements in lower extremity strength were associated with better sprint and agility performance in soccer athletes. The present findings extend previous evidence by demonstrating similar associations specifically within adolescent futsal players, a population characterized by frequent multidirectional movement demands performed in smaller playing areas and shorter recovery intervals compared with outdoor soccer.[2,4] This distinction is important because futsal requires repeated high-intensity directional transitions under confined spatial constraints, potentially increasing the relevance of lower limb strength for movement efficiency.

The substantial variability observed in lower limb muscle strength values among participants may also reflect differences in biological maturation, neuromuscular development, and training adaptation during adolescence.[20] Adolescence is characterized by rapid increases in muscle mass, neural recruitment efficiency, and anaerobic performance capacity, all of which may influence strength and agility performance.[16] Consequently, maturational status may partially explain inter-individual variability in agility outcomes among youth athletes. Although biological maturation was not directly measured in the present study, this factor should be considered when interpreting the findings because adolescent athletes of similar chronological age may differ substantially in physical development and neuromuscular capacity.

Core muscle endurance also demonstrated a strong association with agility performance. This finding supports the concept that trunk stabilization plays a critical role in maintaining efficient movement mechanics during rapid directional changes. The core musculature functions as a kinetic link between the upper and lower extremities and contributes to lumbopelvic stability during dynamic athletic movement.[15] Adequate trunk endurance may allow athletes to maintain postural control and optimize force transfer during repeated acceleration and deceleration tasks, thereby improving movement efficiency and reducing unnecessary energy expenditure.[17]

The slightly stronger standardized beta coefficient observed for core muscle endurance compared with lower limb muscle strength may indicate that trunk stabilization capacity has a substantial role in multidirectional movement control among adolescent futsal players. During agility tasks, inadequate trunk stability may impair balance control and alter lower extremity biomechanics, leading to less efficient movement execution and prolonged directional transition time.[7,18] Previous investigations by Horníková and Zemková10 and Imai and Kaneoka11 similarly reported that trunk endurance and stabilization capacity were associated with athletic movement performance and change-of-direction ability in adolescent athletes.

The use of the McGill's Torso Endurance Test in this study also allowed a more comprehensive evaluation of trunk musculature through flexor, extensor, and lateral stabilization components. These muscle groups collectively contribute to maintaining spinal stability and controlling rotational movement during cutting and pivoting maneuvers commonly performed in futsal.[17] Athletes with greater trunk endurance may therefore exhibit improved postural control during repeated multidirectional actions, which may positively influence agility-related performance.

From a practical perspective, the present findings have potential implications for sports physiotherapy and athletic conditioning in youth futsal. Although causal conclusions cannot be established because of the cross-sectional design, the observed associations suggest that lower limb strengthening and trunk endurance training may represent relevant components within futsal conditioning programs. In addition to performance considerations, improved neuromuscular control and trunk stabilization may also contribute to reducing the risk of non-contact lower extremity injuries during high-intensity directional movements.[9] However, future longitudinal and intervention-based studies are necessary to determine whether targeted training interventions directly improve agility performance and injury-related outcomes in adolescent futsal athletes.

Several methodological considerations should be acknowledged when interpreting the findings. First, the cross-sectional design limits causal inference and does not allow determination of directional relationships between variables. Reverse associations are possible, whereby athletes with better agility performance may also develop superior strength and trunk endurance through repeated sport participation. Second, participants were recruited using purposive sampling from only two futsal clubs in Denpasar City, which may limit generalizability to broader futsal populations with different competitive levels or training characteristics. Third, biological maturation, playing position, training experience, and competitive level were not directly controlled despite their potential influence on physical performance outcomes.

Additional limitations include the use of an isometric leg dynamometer, which may not fully represent the dynamic muscle actions involved during actual agility performance. Agility tasks require complex eccentric-concentric muscle interactions performed under sport-specific movement conditions, whereas isometric assessment evaluates force production in a static condition. Furthermore, participant motivation during physical testing may have influenced maximal performance outcomes despite standardized procedures and familiarization sessions. Finally, although no severe multicollinearity or missing data were identified, the regression model did not include additional biomechanical or neuromuscular variables that may contribute to agility performance, such as reaction time, sprint speed, balance, or movement technique.

Despite these limitations, this study provides clinically relevant findings regarding physical attributes associated with agility in adolescent futsal players. The study also addresses an important research gap because previous investigations have predominantly focused on soccer athletes or adult populations rather than adolescent futsal players. Future studies are recommended to incorporate longitudinal or experimental designs, objective maturation assessment, larger multicenter samples, and sport-specific biomechanical analysis to improve understanding of agility-related performance factors in futsal athletes.

Conclusion

This study demonstrated significant associations between lower limb muscle strength, core muscle endurance, and agility in adolescent male futsal players in Denpasar City. Greater lower limb muscle strength and higher core muscle endurance were associated with better agility performance, reflected by lower T-Test completion times. Simultaneous regression analysis further demonstrated that both variables remained significantly associated with agility performance within the same analytical model.

These findings highlight the potential importance of lower extremity force production capacity and trunk stabilization endurance in multidirectional movement performance among youth futsal athletes. From a practical perspective, the results may assist sports physiotherapists, strength and conditioning coaches, and futsal trainers in considering lower limb strengthening and core endurance exercises as relevant components of youth futsal conditioning programs.

Study Limitations

Several limitations should be considered when interpreting the findings of this study. First, the cross-sectional design does not permit causal inference between lower limb muscle strength, core muscle endurance, and agility performance. Second, participants were recruited using purposive sampling from only two futsal clubs in Denpasar City, which may limit generalizability to broader adolescent futsal populations. Third, biological maturation, playing position, training experience, and competitive level were not directly controlled despite their potential influence on physical performance outcomes. In addition, the use of an isometric leg dynamometer may not fully represent the dynamic muscle actions involved during actual agility performance.

Practical Implications

The present findings may provide practical implications for sports physiotherapy and athletic conditioning programs in adolescent futsal athletes. Training programs emphasizing lower limb muscle strengthening and trunk endurance development may represent relevant strategies to support multidirectional movement performance and neuromuscular control during futsal activities. Furthermore, improving trunk stabilization and lower extremity force capacity may potentially contribute to injury-prevention strategies during high-intensity change-of-direction movements commonly performed in futsal.

Future Research Recommendations

Future studies are recommended to use longitudinal or intervention-based designs to clarify causal relationships between physical performance variables and agility outcomes. Additional investigations incorporating objective maturation assessment, multicenter recruitment, biomechanical analysis, and sport-specific performance testing are also necessary to improve external validity and clinical applicability.

Author Contributions

Ni Putu Anggita Cahya Primardani: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft Preparation, Visualization.
Anak Agung Gede Eka Septian Utama: Supervision, Methodology, Validation, Writing – Review and Editing.
Anak Agung Gede Angga Puspa Negara: Supervision, Validation, Writing – Review and Editing.
I Putu Gde Surya Adhitya: Supervision, Resources, Writing – Review and Editing.

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Conflict of Interest

The authors declare no conflict of interest related to this study.

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Ethical Approval

Ethical clearance was not required for this study because all procedures involved non-invasive physical performance assessments conducted during routine athletic evaluation and did not involve medical intervention, biological sampling, or clinical treatment. Participants and their parents or legal guardians provided written informed consent prior to data collection.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request

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