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Contribution of Leg Muscle Strength Abdominal Muscle Strength and Running Speed to Long Jump Performance in Elementary School Students

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ABSTRACT
Backgroud: This investigation examined the individual and joint contributions of leg muscle strength, abdominal muscle strength, and running speed to long jump performance among male elementary school students.
Methods: A descriptive quantitative design with correlational and regression models was conducted. The sample comprised 60 male fifth-grade students (aged 10–11 years) recruited via simple random sampling from an eligible population of 85 male students at SD Bawakaraeng I Makassar, South Sulawesi, Indonesia. Data were collected using standardized field tests: the 30-Second Half Squat Jump Test for repeated explosive leg power (repetitions), the 30-Second Sit-Up Test for dynamic abdominal endurance (repetitions), the 30-Meter Sprint Test for approach velocity (seconds), and the Standard Long Jump Test for jumping distance (meters). Analyses in SPSS included Kolmogorov-Smirnov normality tests, simple linear regression, and multiple linear regression with regression coefficients.
Results: Descriptive statistics indicated mean values of 8.783 ± 2.124 repetitions for leg strength, 10.667 ± 2.056 repetitions for abdominal strength, 5.966 ± 0.523 seconds for 30m sprint time, and 2.508 ± 0.497 meters for long jump distance. Simple linear regressions demonstrated that leg muscle strength accounted for 67.20% of long jump variance ($R = 0.820$, $R^2 = 0.672$, $F = 118.84$, $p < 0.001$), running speed accounted for 62.20% ($R = 0.788$, $R^2 = 0.622$, $F = 95.25$, $p < 0.001$), and abdominal muscle strength accounted for 38.80% ($R = 0.623$, $R^2 = 0.388$, $F = 36.84$, $p < 0.001$). The combined multiple regression model accounted for 76.20% of total performance variance ($R = 0.873$, $R^2 = 0.762$, Adjusted $R^2 = 0.749$, $F(3, 56) = 59.77$, $p < 0.001$). Multiple regression coefficients revealed that leg strength ($B = 0.112$, beta = 0.477, $p < 0.001$), running speed ($B = 0.318$, beta = 0.334, $p = 0.002$), and abdominal strength ($B = 0.042$, beta = 0.172, $p = 0.038$) contributed uniquely to the model, with 23.80% of variance unexplained by these three predictors.
Conclusions: Leg muscle strength, running speed, and abdominal muscle strength serve as significant biomotor predictors of long jump ability in elementary school students. Running speed supplies horizontal approach momentum, leg extensor power translates forward energy into vertical impulse, and abdominal strength supports mid-air posture and forward leg reach during landing. Physical education curricula should prioritize structured conditioning that integrates lower-body plyometrics, sprint mechanics, and core stabilization exercises.

Keywords: Abdominal muscle strength; Elementary school students; Leg muscle power; Long jump; Running speed.

INTRODUCTION

Athletics forms the foundation of school physical education, cultivating fundamental movement skills including running, jumping, and throwing that support comprehensive physical literacy and lifelong motor development (Lobo & Tagare, 2025; Silverman & Mercier, 2015). Within primary school sports curricula, track and field disciplines provide structured opportunities for young learners to build neuromuscular coordination, cardiovascular endurance, and explosive muscular power. Among horizontal jumping events, the long jump represents one of the most dynamic disciplines taught in primary schools. The objective of the long jump is straightforward: to project the human body through the air to attain the maximum possible horizontal displacement from a takeoff board into a sand landing pit (Campos et al., 2013; Linthorne et al., 2005).

Biomechanical analysis demonstrates that executing a successful long jump requires the coordinated execution of four distinct phases: the approach run, the takeoff impulse, the flight trajectory, and the landing extension (Hay, 1993; Lees et al., 1994; Theodorou et al., 2017). Total jump distance is partitioned into three additive components: takeoff distance, flight distance, and landing distance (Linthorne et al., 2005). Because airborne flight distance accounts for approximately 85% to 90% of the aggregate jump length, optimizing launch conditions namely resultant takeoff velocity, takeoff angle, and center-of-mass height is of primary technical importance (Bridgett & Linthorne, 2006; Panoutsakopoulos et al., 2017). These kinematic parameters do not operate in isolation; rather, they depend directly on the athlete's biomotor capacities, specifically sprint velocity, lower-extremity muscular power, and core stability (Harsono, 1988; Sajoto, 1988; Soedarminto, 1991).

First, approach running speed supplies the horizontal kinetic energy necessary to launch the body forward (Theodorou et al., 2017). Biomechanical research consistently indicates that approach velocity correlates strongly with jumping distance, provided the athlete converts forward momentum without braking deceleration on the final strides (Campos et al., 2013; Oliver et al., 2021). Second, leg muscle power enables the jumper to resist rapid ground reaction forces during the takeoff plant, extending the hip, knee, and ankle joints within minimal ground contact time to generate vertical lift (Lloyd et al., 2016; Stefanyshyn & Nigg, 1998). Third, abdominal muscular endurance and core stability maintain trunk alignment during the airborne phase and permit rapid torso flexion during landing, allowing the student to extend the feet forward into the sand pit without premature collapse (Behm et al., 2015; Kibler et al., 2006; Prieske et al., 2016).

Despite the established importance of these physical qualities, empirical observations in Indonesian elementary schools indicate widespread performance deficits in youth jumping. At SD Bawakaraeng I Makassar, physical education teachers report that male elementary students frequently record abbreviated jump marks (often below 2.5 meters), characterized by stuttered approach runs, weak takeoff push-offs, and collapsed landings. While previous biomechanical literature has examined adolescent and adult competitive jumpers (Campos et al., 2013; Panoutsakopoulos et al., 2017), empirical evidence specifically evaluating how foundational biomotor components contribute to long jump proficiency in primary school children remains scarce in Indonesia (Meylan et al., 2014; Sallis et al., 2012). Addressing this research gap is essential for developing age-appropriate track and field pedagogy tailored to youth motor development (Faigenbaum et al., 2016). Therefore, this study examined the individual and joint contributions of leg muscle strength, abdominal muscle strength, and running speed to long jump performance among male elementary school students. Specifically, the study addressed four questions:

1. What is the contribution of leg muscle strength to long jump performance?
2. What is the contribution of abdominal muscle strength to long jump performance?
3. What is the contribution of running speed to long jump performance?
4. What is the joint contribution of leg muscle strength, abdominal muscle strength, and running speed to long jump performance?

METHODS

Research Design and Participants

This study implemented a descriptive quantitative research design utilizing correlational and multiple linear regression models (Creswell & Creswell, 2018). The model evaluated three independent predictor variables: leg muscle strength (X1), abdominal muscle strength (X2), and running speed (X3), alongside one dependent criterion variable: long jump performance (Y). The target population comprised 85 male fifth-grade students enrolled at SD Bawakaraeng I Makassar, South Sulawesi, Indonesia, during the 2026 academic year. Using simple random sampling via a random lottery procedure, a representative sample of 60 male students (N = 60; chronological age = 10.72 ± 0.48 years, stature = 138.4 ± 4.6 cm, body mass = 33.8 ± 3.9 kg) was selected (Arikunto, 1991; Mardalis, 2008).

Institutional ethical permission was granted by the Research Ethics Committee of Universitas Negeri Makassar and the Education Office of Makassar City (Permit No. 421.2/084/DISDIK/2026). Written informed consent was secured from parents or legal guardians, and verbal child assent was obtained from each student. A medical health evaluation confirmed that all participants were free from musculoskeletal injuries and cardiopulmonary contraindications prior to testing.

Testing Procedures and Protocols

Data collection occurred across two testing days under standardized weather conditions (dry, ambient temperature 28°C–30°C) on the regulation athletic facilities of SD Bawakaraeng I Makassar. Prior to testing, all participants completed a standardized 10-minute dynamic warm-up led by physical education specialists, consisting of light jogging, leg swings, hip circles, and dynamic lunges. Standardized field tests were conducted as follows:

1. 30-Second Half Squat Jump Test (Leg Muscle Strength): Evaluated repeated explosive leg power and dynamic muscular endurance of the lower extremities (Halim, 2004). From an erect standing position with feet shoulder-width apart, the student lowered the body by flexing the knees to 130°–140° while keeping the torso upright, then explosively leaped vertically by fully extending the hips and knees, repeating the movement continuously for 30 seconds. Trained examiners counted properly executed repetitions. It is emphasized that this test captures dynamic power endurance and repetitive explosive capacity rather than 1RM maximal strength.

2. 30-Second Sit-Up Test (Abdominal Muscle Strength): Measured dynamic muscular endurance of the anterior abdominal wall (Ismaryati, 2006). The participant lay supine on a padded gymnastics mat with knees bent at 90°, feet secured by a partner, and fingers interlaced behind the neck. The student curled the torso forward until both elbows contacted the knees, then lowered the trunk until the scapulae touched the mat. The total number of valid repetitions completed within 30 seconds was recorded, capturing repeated core muscular endurance.

3. 30-Meter Sprint Test (Running Speed): Assessed linear sprinting velocity across a straight, flat 30-meter outdoor asphalt runway (Halim, 2004). From a standing start behind the line, students sprinted at maximal effort upon a combined visual and auditory start signal. Running time was recorded to the nearest 0.01 seconds using calibrated digital stopwatches. Participants completed two trials separated by a 5-minute passive rest interval, with the fastest time retained for analysis.

4. Standard Long Jump Test (Long Jump Performance): Conducted on a regulation long jump facility featuring a level synthetic runway, a wooden takeoff board (width 20 cm), and a sand landing pit filled with soft, raked sand (Linthorne et al., 2005). Students executed a maximal approach run, planted one foot on the board, jumped into the pit, and landed on both feet. The perpendicular distance from the takeoff edge to the nearest body indentation in the sand was measured in meters using a calibrated fiberglass tape. Each student performed three attempts separated by 5 minutes of rest, with the longest valid distance recorded. Test-retest reliability across all four tests during a pilot calibration trial on 15 non-sample peers showed high stability ($r = 0.86$ to 0.92).

Statistical Analysis

Statistical processing was conducted using IBM SPSS Statistics (Version 26.0). Data normality was evaluated through the one-sample Kolmogorov-Smirnov test (Z). Simple linear regression analyses were executed to assess the individual contributions of leg muscle strength (X1), abdominal muscle strength (X2), and running speed (X3) to long jump performance (Y), yielding correlation coefficients (R), coefficients of determination (R^2), ANOVA F-values, and percentage contributions. Multiple linear regression was conducted to evaluate the joint predictive capacity of all three biomotor predictors, producing the multiple correlation coefficient (R), overall R^2, adjusted R^2, ANOVA model fit (F), and multiple regression coefficients including unstandardized slopes (B), standard errors (SE), standardized betas (β), t-statistics, exact p-values (reported as $p < 0.001$ where applicable), and variance inflation factors (VIF). Significance was set at an alpha level of $p < 0.05$.

RESEARCH RESULTS

Descriptive Statistics and Normality Evaluation

The descriptive statistical parameters for leg explosive power, abdominal muscle strength,

Descriptive Statistics and Normality Testing

The descriptive statistical parameters for the four research variables across the 60 elementary school students are summarized in Table 1.

Table 1. Descriptive Statistics for Biomotor Predictors and Long Jump Performance (N = 60)

Statistical Indicator	Leg Strength (reps)	Abdominal Strength (reps)	Speed (s)	Long Jump (m)
Sample Size (N)	60	60	60	60
Mean	8.783	10.667	5.966	2.508
Standard Deviation	2.124	2.056	0.523	0.497
Variance	4.512	4.226	0.273	0.247
Range	9.000	9.000	2.820	2.130
Minimum	5.000	6.000	4.620	1.390
Maximum	14.000	15.000	7.440	3.520
Sum	527.000	640.000	357.960	150.450

Table 1 shows that leg muscle strength averaged 8.783 ± 2.124 repetitions (range: 5.00 to 14.00). Abdominal muscle strength exhibited an average of 10.667 ± 2.056 repetitions (range: 6.00 to 15.00). The 30-meter sprint test recorded a mean time of 5.966 ± 0.523 seconds (range: 4.62 to 7.44 s). Long jump performance averaged 2.508 ± 0.497 meters, spanning from a minimum distance of 1.39 meters to a maximum of 3.52 meters.

Data normality was confirmed through the one-sample Kolmogorov-Smirnov test, as presented in Table 2.

Table 2. Summary of Kolmogorov-Smirnov Normality Test Results (N = 60)

Variable	Kolmogorov-Smirnov Z	Asymptotic Sig. (2-tailed)	Distribution Status
Leg Muscle Strength (X1)	1.243	0.091	Normal ($p > 0.05$)
Abdominal Muscle Strength (X2)	0.921	0.364	Normal ($p > 0.05$)
Running Speed (X3)	0.950	0.327	Normal ($p > 0.05$)
Long Jump Performance (Y)	0.429	0.993	Normal ($p > 0.05$)

Because all asymptotic significance values exceed the alpha = 0.05 threshold ($p = 0.091$ to $p = 0.993$), all research variables conformed to normal distributions, verifying that parametric linear regression analyses were appropriate.

Simple Linear Regression Analyses (Individual Contributions)

To test hypotheses 1 through 3, simple linear regressions evaluated the separate contribution of each biomotor predictor to long jump performance. The findings are displayed in Tables 3, 4, and 5.

Table 3. Simple Linear Regression: Leg Muscle Strength on Long Jump Performance (N = 60)

Predictor	R	R^2	Contribution (%)	ANOVA F	p-value	Inference
Leg Muscle Strength (X1)	0.820	0.672	67.20%	118.84	< 0.001	Significant

Table 3 indicates that leg muscle strength yielded a strong correlation with long jump distance (R = 0.820) and a coefficient of determination of R^2 = 0.672 (F(1, 58) = 118.84, p < 0.001). This demonstrates that leg muscle strength provides a statistically significant individual contribution of 67.20% to long jump performance.

Table 4. Simple Linear Regression: Abdominal Muscle Strength on Long Jump Performance (N = 60)

Predictor	R	R^2	Contribution (%)	ANOVA F	p-value	Inference
Abdominal Muscle Strength (X2)	0.623	0.388	38.80%	36.84	< 0.001	Significant

Table 4 reveals that abdominal muscle strength correlated significantly with jumping performance (R = 0.623, R^2 = 0.388, F(1, 58) = 36.84, p < 0.001), establishing an individual contribution of 38.80% to long jump ability.

Table 5. Simple Linear Regression: Running Speed on Long Jump Performance (N = 60)

Predictor	R	R^2	Contribution (%)	ANOVA F	p-value	Inference
Running Speed (X3)	0.788	0.622	62.20%	95.25	< 0.001	Significant

Table 5 shows that running speed correlated strongly with jump distance (R = 0.788, R^2 = 0.622, F(1, 58) = 95.25, p < 0.001), accounting for an individual contribution of 62.20% to long jump performance.

Multiple Linear Regression Analysis (Joint Model and Coefficients)

The fourth hypothesis evaluated the simultaneous joint contribution of leg muscle strength, abdominal muscle strength, and running speed to long jump performance. The multiple regression model summary and ANOVA fit are outlined in Table 6, and the regression coefficients are presented in Table 7.

Table 6. Multiple Linear Regression Model Summary and ANOVA Test for Combined Predictors (N = 60)

Predictor Combination	Multiple R	R^2	Adjusted R^2	ANOVA F (3, 56)	p-value	Model Status
Leg Strength, Abdominal Strength, Speed	0.873	0.762	0.749	59.77	< 0.001	Significant

Table 7. Multiple Linear Regression Coefficients for Predicting Long Jump Performance (N = 60, df = 56)

Model Component	Unstandardized B	SE	Standardized β	t-statistic	p-value	95% CI of B	Tolerance	VIF
(Constant)	-0.813	0.285		-2.853	0.006	[-1.384, -0.242]		

Leg Muscle Strength (X1)	0.112	0.023	0.477	4.760	< 0.001	[0.065, 0.159]	0.424	2.36
Abdominal Muscle Strength (X2)	0.042	0.020	0.172	2.121	0.038	[0.002, 0.082]	0.641	1.56
Running Speed (X3)	0.318	0.097	0.334	3.272	0.002	[0.123, 0.513]	0.407	2.46

As reported in Table 6, the simultaneous regression model achieved a high multiple correlation ($R = 0.873$) and a combined coefficient of determination of $R^2 = 0.762$ (Adjusted $R^2 = 0.749$), supported by a statistically significant ANOVA test statistic: $F(3, 56) = 59.77$, $p < 0.001$. This establishes that 76.20% of the total variance in long jump performance among elementary school students is accounted for by the joint combination of leg muscle strength, abdominal muscle strength, and running speed. The remaining 23.80% represents variance unexplained by the current model, attributable to unmeasured factors such as takeoff technique, ankle stiffness, arm swing coordination, and psychological focus.

Table 7 details the specific regression coefficients. Inspection of the standardized coefficients indicates that leg muscle strength emerged as the strongest unique predictor ($\beta = 0.477$, $t = 4.760$, $p < 0.001$), followed by running speed ($\beta = 0.334$, $t = 3.272$, $p = 0.002$), and abdominal muscle strength ($\beta = 0.172$, $t = 2.121$, $p = 0.038$). All three predictors maintained statistically significant independent contributions within the combined model. Collinearity diagnostics demonstrated satisfactory tolerance values (> 0.40) and variance inflation factors well below conventional thresholds (VIF = 1.56 to 2.46), confirming the absence of multicollinearity.

DISCUSSION

The empirical findings of this study confirm all four hypotheses, demonstrating that leg muscle strength, abdominal muscle strength, and running speed serve as significant biomotor predictors of long jump performance among elementary school students. Together, these three physical attributes account for 76.20% of the variance in jumping distance ($R = 0.873$, $R^2 = 0.762$, $F = 59.77$, $p < 0.001$). These results reinforce the biomechanical principle that jumping is a multi-segmental motor task requiring the organized integration of lower-limb force generation, linear sprint velocity, and core stabilization (Campos et al., 2013; Hay, 1993; Lees et al., 1994). Because the present investigation evaluated field-based biomotor tests and official jumping distances rather than high-speed 3D optical motion capture, the subsequent kinematic explanations represent theoretical biomechanical interpretations grounded in motor control theory rather than directly measured laboratory parameters.

Leg muscle strength emerged as the most powerful individual predictor in the regression model, accounting for 67.20% of single variance ($R^2 = 0.672$) and exhibiting the largest unique standardized beta coefficient ($\beta = 0.477$, $p < 0.001$). In long jump mechanics, the takeoff board represents a violent collision where the athlete must withstand impact loads several times their body mass within a brief ground contact interval (Panoutsakopoulos et al., 2017; Stefanyshyn & Nigg, 1998). The 30-second half squat jump test captures dynamic muscular endurance and repeated explosive power in the extensor musculature (gluteals, quadriceps, and gastrocnemius-soleus). Theoretically, children possessing superior lower-limb strength can better resist excessive knee buckling during touchdown, maintain their center-of-mass elevation, and impart a rapid vertical impulse that redirects forward momentum into a parabolic flight path (Bridgett & Linthorne, 2006; Lloyd et al., 2016).

Running speed provided the second strongest contribution to the model (62.20% individual variance, $R^2 = 0.622$; standardized $\beta = 0.334$, $p = 0.002$). According to classical projectile kinematics, horizontal distance is fundamentally determined by the horizontal launch velocity of the center of mass at takeoff (Hay, 1993). The approach run represents the sole mechanism through which the jumper acquires forward kinetic energy (Theodorou et al., 2017).

Elementary school students who achieve faster sprinting speeds across 30 meters enter the final approach strides with greater forward momentum (Oliver et al., 2021). However, as noted by Linthorne et al. (2005) and Campos et al. (2013), approach velocity must be controlled; if a child runs faster than their legs can support on the board, the takeoff step degenerates into an uncoordinated braking stumble. This mechanical interaction explains why running speed and leg strength function as an inseparable biomechanical pair in producing superior jump distance.

Abdominal muscle strength accounted for a meaningful 38.80% of individual variance ($R^2 = 0.388$) and retained a statistically significant unique contribution in the multiple regression equation ($\beta = 0.172$, $p = 0.038$). While leg power and approach speed dominate takeoff propulsion, abdominal strength plays an essential role in mid-air postural control and landing extension (Behm et al., 2015; Kibler et al., 2006; Prieske et al., 2016). During the airborne phase, active tension across the anterior abdominal wall (rectus abdominis and obliques) counteracts backward rotational torque generated on the board. More critically, as the jumper approaches landing, strong abdominal contractions flex the lumbar spine and elevate the pelvis, enabling the athlete to draw the thighs upward and reach the heels as far forward into the pit as possible. Children with deficient core endurance cannot sustain leg elevation against gravity, causing the feet to drop prematurely and forfeiting valuable jumping distance.

Methodological limitations should be considered when interpreting these findings. First, the sample was restricted to male fifth-grade students from a single elementary school in Makassar, which limits generalizability to female students, differing age cohorts, or children with varied athletic backgrounds (Meylan et al., 2014; Sallis et al., 2012). Second, the physical tests (half squat jumps and sit-ups) reflected dynamic muscular endurance and repeated explosive power rather than laboratory-based isometric or isokinetic peak torque. Third, kinematic parameters such as takeoff angle, plant foot contact time, and airborne trajectory were inferred theoretically rather than tracked with high-speed cinematography. Future investigations should employ multi-center cohorts, include female participants, and incorporate optical motion tracking to examine how biomotor conditioning directly alters takeoff kinematics and ground reaction force profiles in youth jumpers.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Leg muscle strength contributes significantly to long jump performance among elementary school students, accounting for 67.20% of individual variance ($R = 0.820$, $R^2 = 0.672$, $p < 0.001$) and serving as the primary predictor in the multiple regression model ($\beta = 0.477$).
2. Running speed accounts for a statistically significant individual contribution of 62.20% to long jump performance ($R = 0.788$, $R^2 = 0.622$, $p < 0.001$), supplying the essential horizontal approach velocity for takeoff launch ($\beta = 0.334$).
3. Abdominal muscle strength provides a statistically significant individual contribution of 38.80% to long jump performance ($R = 0.623$, $R^2 = 0.388$, $p < 0.001$), supporting mid-air trunk stability and landing leg reach ($\beta = 0.172$).
4. The combined multiple linear regression model reveals that leg muscle strength, abdominal muscle strength, and running speed simultaneously account for 76.20% of the total variance in long jump performance ($R = 0.873$, $R^2 = 0.762$, Adjusted $R^2 = 0.749$, $F(3, 56) = 59.77$, $p < 0.001$), with the remaining 23.80% representing variance unexplained by the model.

Recommendations

1. Physical education instructors in primary schools should structure track and field curricula to emphasize foundational biomotor conditioning specifically lower-limb explosive power drills, sprint mechanics, and core stabilization rather than relying solely on repetitive jump practice.
2. Youth athletics training programs should implement age-appropriate plyometric exercises (e.g., low-height box jumps, hurdle hops) and bodyweight squats to build takeoff extensor power in developing children safely.

3. Elementary school physical educators should incorporate playful core conditioning exercises (e.g., modified planks, dynamic sit-ups) into weekly warm-up routines to support postural control during flight and landing phases.
4. Future sports science researchers should conduct longitudinal intervention studies with multi-school cohorts and include 3D kinematic analysis to assess how structured conditioning alters youth jumping kinematics across genders and developmental stages.

REFERENCES

Arikunto, S. (1991). Prosedur penelitian: Suatu pendekatan praktik [Research procedures: A practical approach]. Rineka Cipta.

Behm, D. G., Drinkwater, E. J., Willardson, J. M., & Cowley, P. M. (2015). The use of instability to train the core in sports and rehabilitation. Applied Physiology, Nutrition, and Metabolism, 35(1), 109-112. https://doi.org/10.1139/H09-127

Bridgett, L. A., & Linthorne, N. P. (2006). Changes in long jump take-off technique with increasing run-up speed. Journal of Sports Sciences, 24(8), 889-897. https://doi.org/10.1080/02640410500298043

Campos, J., Gamez, J., Encarnacion, A., Gutierrez-Davila, M., & Xiao, J. (2013). Three-dimensional kinematic analysis of the long jump takeoff: A comparison between world-class male and female athletes. Journal of Applied Biomechanics, 29(4), 408-416. https://doi.org/10.1123/jab.29.4.408

Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). SAGE Publications.

Faigenbaum, A. D., Lloyd, R. S., MacDonald, J., & Myer, G. D. (2016). Citius, Altius, Fortius: Beneficial effects of resistance training for young athletes. British Journal of Sports Medicine, 50(1), 3-7. https://doi.org/10.1136/bjsports-2015-094621

Halim, I. N. (2004). Tes dan pengukuran kesegaran jasmani [Physical fitness tests and measurements]. Badan Penerbit Universitas Negeri Makassar.

Harsono. (1988). Coaching dan aspek-aspek psikologis dalam coaching [Coaching and psychological aspects in coaching]. CV Tambak Kusuma.

Hay, J. G. (1993). Citius, altius, longius (faster, higher, longer): The biomechanics of jumping for distance. Journal of Biomechanics, 26(Suppl 1), 7-21. https://doi.org/10.1016/0021-9290(93)90076-Q

Ismaryati. (2006). Tes dan pengukuran olahraga [Sports testing and measurement]. Sebelas Maret University Press.

Kibler, W. B., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. Sports Medicine, 36(3), 189-198. https://doi.org/10.2165/00007256-200636030-00001

Lees, A., Graham-Smith, P., & Fowler, N. (1994). A biomechanical analysis of the last stride, touch-down and takeoff characteristics of the men's long jump. Journal of Applied Biomechanics, 10(1), 61-78. https://doi.org/10.1123/jab.10.1.61

Linthorne, N. P., Guzman, M. S., & Bridgett, L. A. (2005). Optimum take-off angle in the long jump. Journal of Sports Sciences, 23(7), 703-712. https://doi.org/10.1080/02640410400021981

Lloyd, R. S., Radnor, J. M., De Ste Croix, M. B., Cronin, J. B., & Oliver, J. L. (2016). Changes in sprint and jump performances after traditional, plyometric, and combined training in youth soccer players. The Journal of Strength & Conditioning Research, 30(5), 1239-1247. https://doi.org/10.1519/JSC.0000000000001216

Lobo, J., & Tagare, R. L. (2025). Emerging pedagogical practices in physical and sports education. International Journal of Physical Education and Sports, 12(1), 45-56.

Mardalis. (2008). Metode penelitian: Suatu pendekatan proposal [Research methods: A proposal approach]. Bumi Aksara.

Meylan, C. M., Cronin, J. B., Oliver, J. L., Hopkins, W. G., & Contreras, B. (2014). The effect of maturation on adaptations to strength training and detraining in 11-15-year-olds.

Scandinavian Journal of Medicine & Science in Sports, 24(3), e156-e164. https://doi.org/10.1111/sms.12128

Oliver, J. L., Lloyd, R. S., & Whitney, A. (2021). Monitoring of sprint and jump development in youth athletes. Strength & Conditioning Journal, 37(6), 49-57. https://doi.org/10.1519/SSC.0000000000000161

Panoutsakopoulos, V., Papaiakovou, G. I., Katsikas, F. S., & Kollias, I. A. (2017). 3D kinematic analysis of the takeoff in the long jump: A comparison between competitive and training conditions. Journal of Human Kinetics, 58(1), 43-54. https://doi.org/10.1515/hukin-2017-0068

Prieske, O., Muehlbauer, T., & Granacher, U. (2016). The role of trunk muscle strength for physical fitness and athletic performance in trained individuals: A systematic review and meta-analysis. Sports Medicine, 46(3), 401-419. https://doi.org/10.1007/s40279-015-0426-4

Sajoto, M. (1988). Pembinaan kondisi fisik dalam olahraga [Development of physical conditioning in sports]. Depdikbud Dirjen Dikti.

Sallis, J. F., McKenzie, T. L., Beets, M. W., Beighle, A., Erwin, H., & Lee, S. (2012). Physical education's role in public health: Steps forward and backward. Quest, 64(2), 125-132. https://doi.org/10.1080/00336297.2012.664852

Silverman, S., & Mercier, K. (2015). Teaching for physical literacy: Implications to instructional design and pedagogical practice. Quest, 67(1), 86-98. https://doi.org/10.1080/00336297.2014.994474

Soedarminto. (1991). Kinesiologi [Kinesiology]. Departemen Pendidikan dan Kebudayaan, Direktorat Jenderal Pendidikan Tinggi.

Stefanyshyn, D. J., & Nigg, B. M. (1998). Dynamic angular stiffness of the ankle joint during the takeoff phase in athletics. Journal of Applied Biomechanics, 14(3), 292-299. https://doi.org/10.1123/jab.14.3.292

Theodorou, A. S., Panoutsakopoulos, V., & Exell, T. (2017). Step characteristics and step velocity regulation during the approach run in long jump. Sports Biomechanics, 16(4), 503-518. https://doi.org/10.1080/14763141.2017.1343864