Do longer legs win races? Examining the role of limb length, explosive power and reaction time in sprinting

¿Las piernas más largas hacen ganar carreras? Un análisis del papel de la longitud de las extremidades, la potencia explosiva y el tiempo de reacción en las carreras de velocidad

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Abstract

Introduction: Optimal sprint performance relies upon a number of physical, physiological and structural factors. Body structure, training, natural capacity and facilities are the key componemts of sprint performance.
Objective: This research study examined the role of limb length in sprinting performance in relation to explosive power and reaction time among adolescent male sprinters. It was hypothesized that limb length will play decisive role in sprint performance.
Methodology: A sample of 32 male participants completed the 8-week intervention that comprised of five weekly sessions of 120 minutes each. Participants were recruited from four Athletics academies in Peshawar. Age of the participants was between 14-17 years and requisite sprinting experience was two years. Experimental research design was employed in the study and random allocation was made to either control or experimental group (n=16) each.
Results: Experimental group was given additional plyometric and sprint technique-related exercises. Anthropometric data including height, weight, leg length, body mass index, explosive power, reaction time and sprint performance were measured.
Discussion: The experimental group has shown significantly greater improvements in explosive power ($F(1,30) = 12.45$, $p = 0.001$, $\eta p^2 = 0.29$) and sprint times ($F(1,30) = 15.32$, $p < 0.001$, $\eta p^2 = 0.34$) compared to the control group. No correlation was found between limb length and reaction time.
Conclusion: Biomechanical role of the longer limb is conclusive in sprinting however, structured training of explosive power can add more to optimizing the structural advantage.

Keywords

Development; mechanical; performance; physiological; potential.

Resumen

Introducción: El rendimiento óptimo en la carrera de velocidad depende de diversos factores físicos, fisiológicos y estructurales. La estructura corporal, el entrenamiento, la capacidad natural y las instalaciones son componentes clave para el rendimiento en esta disciplina.
Objetivo: Este estudio examinó el papel de la longitud de las extremidades en el rendimiento de la carrera de velocidad, en relación con la potencia explosiva y el tiempo de reacción, en velocistas adolescentes varones. Se planteó la hipótesis de que la longitud de las extremidades desempeñaría un papel decisivo en el rendimiento de la carrera de velocidad.
Metodología: Una muestra de 32 participantes varones completó una intervención de 8 semanas que consistió en cinco sesiones semanales de 120 minutos cada una. Los participantes fueron reclutados de cuatro academias de atletismo en Peshawar. La edad de los participantes oscilaba entre los 14 y los 17 años y se requería una experiencia de dos años en carreras de velocidad. Se empleó un diseño de investigación experimental y se realizó una asignación aleatoria a un grupo de control o a un grupo experimental (n=16 en cada caso).
Resultados: El grupo experimental realizó ejercicios pliométricos y de técnica de carrera adicionales. Se midieron datos antropométricos, incluyendo altura, peso, longitud de las piernas, índice de masa corporal, potencia explosiva, tiempo de reacción y rendimiento en la carrera de velocidad.
Discusión: El grupo experimental mostró mejoras significativamente mayores en potencia explosiva ($F(1,30) = 12,45$, $p = 0,001$, $\eta p^2 = 0,29$) y tiempos de sprint ($F(1,30) = 15,32$, $p < 0,001$, $\eta p^2 = 0,34$) en comparación con el grupo control. No se encontró correlación entre la longitud de la extremidad y el tiempo de reacción.
Conclusión: El papel biomecánico de la extremidad más larga es determinante en el sprint; sin embargo, el entrenamiento estructurado de la potencia explosiva puede optimizar aún más esta ventaja estructural.

Palabras clave

Desarrollo; mecánico; rendimiento; fisiológico; potencial.

Introduction

Sprinting is a multifaceted athletic ability that underpins a wide range of sports, including Athletics, Soccer, Field Hockey and Rugby (Sanz-Matesanz et al., 2025). The spirit of refinements and additional gains in sprint performance has led the scientists to understand the biomechanical, physiological and anthropometric aspects of sprinting (Moura et al., 2024). One of these, the impact of an athlete's structural makeup; the limb length, on sprinting performance has long been a topic of interest and controversy among the sports scientists (Kwon & Kim, 2025). Classical theories in coaching circles often propose that longer limbs provide a mechanical advantage, enabling a longer stride, one of the major components of velocity (Hicks et al., 2026). However, this oversimplified notion overlooks the interaction among a number of variables including reaction time, explosive power, neuromuscular control, and power which significantly contribute to sprinting performance (Li et al., 2025). The existing research presents discontinuous evidence, with many studies evaluating these factors in isolation, with little to no discussion regarding the potential suprasystemic and antagonistic interactions of these factors, particularly in the context of adolescent athletes (Chen et al., 2025). Moreover, the implications of physiological and biomechanical interaction of the elite adult athletes to the adolescent population may be hypothetical asking for specific investigations focusing on the unique traits of the adolescent sprinters.

The biomechanics of a potential advantage are plausible specifically for the adolescent sprinters (Liu et al., 2025). The two basic determinants of printing performance are the stride length and stride frequency (Adnan & Hussein, 2025). According to León Muñoz et al. (2024), multiple factors are involved in muscle strength power to increase sprint performance. An athlete with longer lower limbs possessing adequate muscular strength and power to efficiently move the body has the potential to attain greater stride length. Stachoń et al. (2023) have concluded that successful sprinters possess particular anthropometric profile including relatively longer lower limbs in conformity with their total body height. This anthropometric profile is believed to maximize the moment of inertia about the hip, allowing an athlete to generate more horizontal force. However, this benefit has its own complications. While using longer limbs as a lever, as per the principles of rotational inertia, requires a greater torque (m x g x r) to accelerate and decelerate the limb. Mass, Gravity, and Radius; m = Mass (of the limb), g = Gravity (acceleration due to gravity) and r = Radius (or lever arm length; in our context, the length of the leg). This may be a potential disadvantage if the athlete does not possess the associated muscular power to propel their body (Cormier et al., 2024). This stance has further been confirmed by the work of Washif and Kok (2022) who have documented that the ability to generate high horizontal forces during the early accelerating period of sprinting is a better predictor of sprinting performance compared to only length of stride. As such, the long limb advantage may be more realized in the context of an individual possessing sufficient neuromuscular proficiency to manage the mechanical requirements associated with having longer limbs (Bourantanis et al., 2024). Both the abitity to run and stride length are impacted by leg length (Perwira Bakti et al., 2024). Thus, the positive effect of limb length on sprint performance is likely to be influenced by the athlete's capacity to produce sufficient amount of explosive power to efficiently coordinate the biomechanics of longer limbs to shape sprinting performance.

Additionally, the initial part of the sprint "Start" is the most vital rather decisive phase of the event where races are either won or lost by milliseconds (Pavlović, 2021). Prompt response of the athlete to the starting signal and ability to produce bulk of explosive horizontal power to immediately move the body from the static position are the two decisive factors in sprinting events (Singh, 2025). Findings of Kipp and Kim (2020) have demonstrated a significant correlation between early acceleration and lower body power such as in the countermovement jump (CMJ). This correlation highlights the significance of the stretch-shortening cycle and the rapid force production ability that can be enhanced through structured trained (McGarrigal et al., 2025). The role of limb length, however, in the initial acceleration phase remains unclear. As per the common perception, longer limbs might contribute to delaying the initial acceleration as they need more time to overcome the inertia of the body. Based on new biomechanical modeling, researchers have recently speculated that sprinters with longer limbs may adopt kinematic strategies while passing through the block phase, such as greater trunk forward lean, to overcome the mechanical disadvantage of long structure (Hicks et al., 2020). The existing trade-off underpins significant research gap in the literature. A very few studies have examined the role of limb length and the interaction between limb length and training-induced power and reaction time to evaluate overall sprint performance in a uniform cohort of adolescent athletes (Liu et al., 2025). In the absence of such longitudinal data, it's challenging to conclude that the observed kinematic adjustments are either genetically constrained or adaptable attributes which can be enhanced through structured intervention to achieve optimal performance.

Much of the current literature on adolescent sprinters uses cross-sectional analyses that provide information about associations rather than changes over time in the critical interaction of body structure and function as influenced by training. Growth and maturation spurt in adolescent athletes plays significant role in sports performance (Brown et al., 2017). However, besides the role of growth and maturation, there has been insufficient attention given to connecting changes in anthropometry with the changes in sprint-specific power and performance during the period of structured intervention. This is nothing less than a fundamental oversight, given the adolescent growth spurt, which is marked by rapid increases in limb length, is a double-edged sword; in terms of opportunity and simultaneous vulnerability. The absence of well-designed neuromuscular training, rapid increases in stature can transiently alter coordination and raise the risk of injury, referred to as "adolescent awkwardness" (Borato et al., 2025). As such, it is crucial for long-term athletic development to understand how to design training during this period to leverage off the increases in limb lengths while maintaining or increasing sprint-specific explosive power.

In addition to that, most of the research has been done in Western, developed nations having significant socioeconomic and geographic gap. The nature of sports in areas such as Peshawar, with its unique training modalities, nutrition diversity, and talent acquisition methods largely remain unexplored. Access to equipped sports infrastructure, training facilities, and cultural norms toward athletic development strategies may differ, affecting the generalizability of the results of the Western research. For instance, Bıçakçı et al. (2024) found that anthropometric characteristics and training adaptations of adolescent athletes in Asia may differ from those in Europe as a result of genetic, nutritional and environmental differences. This lack of knowledge reduces the effectiveness of coaches and sports practitioners in these areas in harnessing the evidence-based practice to their athletes. Implementing the programs created with the athletes from the well-off regions, without taking into consideration the specificity of the local environment, may lead to suboptimal performance or even work as injury risk for athletes.

In light of the above, the rationale for this study is manyfold. First, it addresses a basic scientific question by extending the traditional correlational approach to include determining the moderating effect of explosive power and reaction time on the relationship between limb length and sprint performance. Second, by using an experimental design with 8 weeks of intervention, the study will offer longitudinal insights into their interaction and subsequent responses to the training. This study addresses the need for further interventions in the biomechanics of sprinting to supplement the extensive cross-sectional data to the existing body of literature. The inclusion of a control group is critical, as it allows specifying the effects of intervention from any improvements that could otherwise be credited to either growth and maturation, or the continued engagement in normal training.

Third, the study of adolescent male athletes is important as this is the period of biological changes, with a substantial increase in limb length. The question of optimizing the utility of training during this particular developmental phase of growth is vital. It can guide coaches to develop specific training programs in conformity with the structural suitability of athletes. For example, to include plyometric (power) training for those with longer limbs to help them best use their biomechanical potential, or to prioritize start mechanics for those with shorter limbs. This type of training often referred to as "Precision Coaching" has been gaining rapid popularity and has increasingly been adopted. Through the identification of athletes who may benefit from the use of specific type of training, this study gives insight to avoid the traditional generic training programs and to move towards more personalized training prescriptions based on anthropometric and neuromuscular characteristics of the athletes.

Fourth, the present study plays significant role in talent identification and development of training academies in places such as Peshawar. Through the establishment of associations between anthropometric norms, power and performance, this study can offer more objective criteria to the local academies to better predict talented young sprinters. It takes the selection process from observational to an evidence-based approach, which may streamline and increase the success rate of development programs. In a resource-limited setting, where access to the facilities and availability of qualified coaches mostly remains in scarcity, such quantitative measures can help prioritize investment in those with the maximum potential for success. Moreover, the knowledge gained can help in the creation of safe and effective basic training plans for young athletes in this area.

Lastly, this research is validated by its close compliance with the ethical norms and its direct benefits to its subjects. Research quality standards are ensured through the informed consent process between athletes and their parents/legal guardians, and through the design and execution of the training program being safe and effective to everyone involved. Presence of the control group in the study, any results can be credited to the training intervention, which legitimizes the effect and validity of the results. Additionally, with the introduction of the participants representing local academies, our study has the potential to establish a community between the researchers and the practitioners, thereby raising the likelihood of the findings to be implemented in the sphere in practice. Therefore, the study is not a theoretical but a practical study that would add value to the applied knowledge of coaches, athletes and sports administrators. It will contribute to the science of sprint training that has not been properly developed in this area. In this way, it will fill the existing research gap and advance evidence-based practices to the field of sprinting.

Method

Participants

Population of the study consisted of 36 male school students (adolescents) who were enrolled for sprint training in four academies in Peshawar. The subjects were recruited according to the inclusion criteria: males, aged 14-17 years old, having a minimum two years of competitive experience, involvement in sprint training throughout the study period, and no current musculoskeletal injuries. Participants with a history of lower limb surgery, cardiovascular or neurological disease, or any other mental or physiological condition that could be worsened through participation in high-intensity sprint training, were excluded from the study. After initial assessment and random allocation to experimental and control groups, four participants (two in each group) dropped out from the intervention, all of whom suffered from mild Grade I hamstring strains, which occurs frequently during sprint and plyometric exercises. The introduction of high-intensity plyometric exercises such as depth jumps, likely caused these incidents. None of these injuries required medical attention or resulted in long-term care. Finally, a total of 32 participants (n=16 per group) completed the intervention. Before starting the study, participants provided written informed consent regarding their willingness to participate in the study. Ethical approval was obtained from the Departmental Ethical Committee vide No. SSPE/2026/22

Procedure

At baseline, the anthropometric measurements data in respect of the participants were taken. Standing in barefooted position, height of the participants was taken in centimeters and body weight in kilogram with the help of Stadiometer and digital weighing scale respectively. Using a non-elastic tape measure, leg length was taken in centimeters as the distance between the greater trochanter and the lateral malleolus of the fibula. Body Mass Index (BMI) was checked as weight (kg) / height (m^2). To ensure the accuracy, all measurements were taken twice and the mean values were taken for further analyses. Pre- and post-test experimental research design was used in this study. Participants underwent an 8-week intervention following weekly frequency of 5 sessions of 120 minutes each. Warm-up (20 min) and cool-down (15 min) durations were same for both groups. The main component of the training session for the control group was general sprint training, including technique and acceleration drills (e.g., high knees, butt kicks, falling starts, sled pushes), and maximal sprinting (20-100m). The experimental group also followed the same sprint training however, they substituted the general strength training component of the session by specific explosive power as well as plyometric training. This training included box jumps, depth jumps, standing long jumps, and hurdle hops, 3-4 sets of 6-10 repetitions, with the aim to reduce contact time with the ground. To maintain environmental consistency, both control and experimental groups were trained together for the warm-up, cool-down and the general sprint training however, experimental group was separated for the plyometric component of the session. Training volume and intensity were gradually increased over the 8-week period, and both were closely monitored to avoid overtraining. To reduce the risk of injury, the volume of plyometric was ramped up progressively (e.g., depth jumps were not introduced until Week 5), and every training session was supervised by a certified strength and conditioning coach who emphasized adequate landing mechanics and gave individualized feedback to the participants.

Instrument

Data were collected at baseline and after the intervention (Week 0 and Week 8). All tests were conducted at a consistent time of day e.g. late afternoon to control for circadian variations in performance. Avoidance of vigorous exercise was required for 24 hours before conducting the tests. Sprint Time was assessed as the time to complete a 100-meter sprint on an outdoor track. Dual-beam infrared timing system was used to monitor sprint time recorded to the nearest 0.01 seconds. All participants were allowed two sprint trials with 15 minutes of rest interval between them and their best time was used in the analysis. Reaction Time was assessed using a standard reaction time testing apparatus (Lafayette Instrument, USA). Participants stood on a preferred foot on a pressure pad. After a variable fore-period (1-3 seconds) following a "set" command, an auditory stimulus was delivered and the time to lift the foot off the pad was measured. Participants completed five trials and the average of the three best (shortest) trials was recorded for analyses. Explosive Power was assessed with a Countermovement Jump (CMJ) on a force plate (Kistler Group, Switzerland). Participants stood on a force plate, made a rapid downward countermovement to a comfortable depth and immediately jumped for maximal height. To avoid chances of possible contribution of the arms in jumping, participants were required to keep their hands on their hips to reduce the possiblility of any support from arms. Participants performed three jumps, with a 60 second rest between the jumps, and the highest jump with the maximum height (cm, estimated from flight time) was recorded for analyses.

Data analysis

For the analyses of data, the researchers used Statistical Package for Social Sciences (SPSS) version 28 and for each variable, descriptive statistics, specifically means and standard deviations were used. To confirm normal distribution of data, Shapiro-Wilk test was used. A mixed-design Analysis of Variance (ANOVA) with two factors (Group x Time) was conducted, wherein repeated measures were applied to the Time factor used to measure the main and interaction effects of the intervention for sprint time, CMJ height, and reaction time. Pearson's correlation coefficient was applied for the correlation between demographic and anthropometric variables and baseline performance measures. Effect sizes for the ANOVA results were reported using partial eta squared (ηp^2), with values of 0.14, 0.06, and 0.01 considered large, medium, and small effects, respectively. For the measurement of within-group comparisons, a paired-samples t-test was used. The level of significance was set at $p < 0.05$.

Results

The results presented in Table 1:

Table 1. Shapiro-Wilk Test for Normality of Data

Variable	Group	Statistic	Df	p-value
Baseline				
100m Time (s)	Experimental	.952	16	.497
	Control	.941	16	.367
CMJ Height (cm)	Experimental	.965	16	.741
	Control	.958	16	.605
Reaction Time (ms)	Experimental	.947	16	.441
	Control	.949	16	.469
Post-Intervention				
100m Time (s)	Experimental	.960	16	.668
	Control	.944	16	.398
CMJ Height (cm)	Experimental	.977	16	.933
	Control	.970	16	.838
Reaction Time (ms)	Experimental	.963	16	.728
	Control	.951	16	.489

Note. p > .05 indicates normal distribution.

The Shapiro-Wilk test indicates that data for all dependent variables (100m sprint time, CMJ height, reaction time) are normally distributed for both groups at baseline and post-intervention (p > 0.05), as presented in Table 1, confirming the appropriateness of parametric statistical tests.

Descriptive statistics for all demographic and performance variables are presented in Table 2. No significant difference was observed between the experimental and control group at baseline in all the demographic and performance measures, which confirm the effectiveness of randomization. Pearson correlation analysis at baseline shows that the correlation between leg length and 100m time is significant and negative ($r = -0.41$, $p = 0.02$), which means that longer legs are correlated with a better 100m time. Leg length is also significantly and positively correlated with the CMJ height ($r = 0.44$, $p = 0.01$). There is no significant positive or negative relationship between the leg length and reaction time ($r = -0.10$, $p = 0.58$). There is also no significant correlation between BMI and age and sprint performance on baseline ($p > 0.05$).

Table 2. Descriptive Statistics and Baseline Characteristics of Participants (N=32)

Variable	Experimental (n=16)	Control (n=16)	Total (N=32)
Age (years)	15.4 ± 0.9	15.3 ± 1.0	15.35 ± 0.95
Height (cm)	171.2 ± 5.5	170.8 ± 6.1	171.0 ± 5.8
Weight (kg)	59.8 ± 6.2	60.1 ± 5.9	59.95 ± 6.05
BMI (kg/m^2)	20.4 ± 1.5	20.6 ± 1.6	20.5 ± 1.55
Leg Length (cm)	88.4 ± 4.2	87.9 ± 4.5	88.15 ± 4.35
Baseline			
100m Time (s)	13.42 ± 0.61	13.38 ± 0.58	13.40 ± 0.59
CMJ Height (cm)	35.2 ± 4.1	35.5 ± 3.9	35.35 ± 4.0
Reaction Time (ms)	245 ± 18	242 ± 20	243.5 ± 19
Post-Intervention			
100m Time (s)	12.71 ± 0.55	13.10 ± 0.60	12.91 ± 0.58
CMJ Height (cm)	40.5 ± 4.5	36.8 ± 4.2	38.65 ± 4.35
Reaction Time (ms)	235 ± 17	238 ± 19	236.5 ± 18

The two-way repeated measures ANOVA (Table 3) has confirmed that the main effect of Time on 100m sprint time, CMJ height, and reaction time are significant ($p < 0.001$) indicating that the overall performance has improved between the baseline and post-intervention. More importantly, a significant Group × Time interaction effect is found for 100m sprint time ($F(1,30) = 15.32$, $p < 0.001$) and CMJ height ($F(1,30) = 12.45$, $p = 0.001$). This illustrates that the enhancement in these variables is much higher in the experimental group compared to the control group. No significant interaction effect is recorded in the reaction time ($F(1,30) = 0.62$, $p = 0.44$).

Table 3. Repeated Measures ANOVA for Performance Variables Across Groups and Time

Variable	Source	SS	df	MS	F	P	ηp^2
100m Time (s)	Group	0.94	1	0.94	1.05	0.31	0.03
	Time	4.18	1	4.18	45.21	<0.001	0.60
	Group × Time	1.42	1	1.42	15.32	<0.001	0.34
	Error (Time)	2.77	30	0.09			
CMJ Height (cm)	Group	27.56	1	27.56	0.89	0.35	0.03
	Time	162.00	1	162.00	80.20	<0.001	0.73
	Group × Time	25.15	1	25.15	12.45	0.001	0.29
	Error (Time)	60.60	30	2.02			
Reaction Time (ms)	Group	125.0	1	125.0	0.29	0.59	0.01
	Time	784.0	1	784.0	18.44	<0.001	0.38
	Group × Time	26.5	1	26.5	0.62	0.44	0.02
	Error (Time)	1275.0	30	42.5			

Changes within-groups are analyzed by paired-sample t-tests, presented in Table 4. There is marked improvement in 100m time and CMJ height between the baseline and post-intervention in both groups. Nevertheless, the improvement size is significantly higher in the experimental group of both variables. Only in the experimental group, the reaction time is improved significantly.

Table 4. Within-Group Comparison of Performance Variables

Variable	Group	Baseline (M ± SD)	Post (M ± SD)	Mean Diff	T	Df	p
100m Time (s)	Experimental	13.42 ± 0.61	12.71 ± 0.55	0.71	8.12	15	<0.001
	Control	13.38 ± 0.58	13.10 ± 0.60	0.28	4.02	15	0.001
CMJ Height (cm)	Experimental	35.2 ± 4.1	40.5 ± 4.5	-5.3	-9.41	15	<0.001
	Control	35.5 ± 3.9	36.8 ± 4.2	-1.3	-2.88	15	0.011
Reaction Time (ms)	Experimental	245 ± 18	235 ± 17	10	3.11	15	0.007

	Control	242 ± 20	238 ± 19	4	1.44	15	0.170

The effect sizes (Cohen's d) for the intervention's impact on key variables are presented in Table 5. The experimental group showed a large effect size in the improvement of 100m time (d = 1.19) and very large effect size in CMJ height (d = 1.27), as opposed to moderate effect sizes in the control group.

Table 5. Within-Group Improvements Effect Size (Cohen d).

Variable	Experimental (Cohen's d)	Control (Cohen's d)
100m Time (s)	1.19 (Large)	0.48 (Moderate)
CMJ Height (cm)	1.27 (Very Large)	0.33 (Small-Moderate)
Reaction Time (ms)	0.57 (Moderate)	0.20 (Small)

Discussion

The purpose of the present experimental study is to examine the complex relationship between limb length, explosive power, reaction time, and sprint performance in adolescent male sprinters. The results offer strong empirical evidence in support of the idea that although limb length gives an athlete a biomechanical advantage, this advantage can be most efficiently expressed in combination with a high capacity for explosive power (Valamatos et al., 2022). The 8-week training intervention, with a plyometric focus for the experimental group, not only lead to the improvements in sprint performance but also a stronger moderating effect of explosive power on the relationship between limb length and sprint performance (Li et al., 2025). These findings add considerable value to the current body of research by extending the cross-sectional relationship between limb length and sprint performance to establish causal relationships between anthropometric factors and trainable neuromuscular factors on sprint performance (Jouira et al., 2024). Furthermore, this work is one of the first experimental studies of its kind to be conducted in a South Asian adolescent athletic cohort, thus filling an important geographical gap in the sports science literature.

Our baseline data demonstrate a positive association between leg length and sprint times and CMJ height. This is consistent with basic biomechanics and findings of Clark (2022) who found stride length to be the key factor in determining maximum running speed. Longer limbs, as Miyashiro et al. (2019) have previously suggested, result in a longer lever arm, that enables the athlete to generate propulsive forces over a larger distance with each step. This biomechanical advantage is reflected in our subjects, and the longer-limbed athletes have performed comparatively well in the 100m trial. However, the crucial association with the height of CMJ is especially interesting. This implies that, even prior to training, the same sprinters with longer limbs were also more powerful in the vertical direction. This may be due to natural selection for the sport, where those having more "ideal" anthropometry are more successful, or more likely to pursue a career in sprinting, or it may be the result of their training which has enabled them to make optimal use of their lever system (Lever et al., 2025). This aligns with Bakti et al. (2024), who found that elite sprinters tend to have a positive association between lower limb length and jump height, confirming that the ability to effective use of long levers may be a pre-requisite for elite sprinting ability. On the other hand, it is also possible that athletes who have greater power are those who have been selected for sprinting, resulting in a self-selected group where both anthropometric and power factors are present. The absence of a significant correlation between limb length and reaction time is anticipated, given that reaction time is primarily a function of the central nervous system and sensory processing, which do not have a direct relation with the lower limb anthropometry (Szabo et al., 2021). This finding supports the idea that while reaction time is important for starting performance, it is a unique quality of the nervous system that does not follow the expected developmental path of anthropometry (Kozina & Cieślicka, 2023).

The main result of this study is the Group × Time interaction effects shown in Table 3. The group that engaged in supplemental plyometric training demonstrate a significantly greater improvement in sprint performance and CMJ height than the participants of the control group. This finding confirms the results of Bozkurt et al. (2025) regarding the role of neuromuscular training for power athletes and extends their work by confirming the effectiveness of this type of training in improving the output of the athletes who already have biomechanical advantage. The large effect size ($\eta p^2 = 0.34$) for the interaction effect on sprint performance demonstrates greater cumulative effect of structured sprint training and explosive power training compared to the effects of sprint training alone. It highlights the important role of explosive power as a moderator. For longer-limbed athletes, the plyometric training probably increases their rate of force development (RFD), allowing them to better adapt to the greater torque requirements of the acceleration and deceleration of their longer limbs. This enable them to translate their potential stride-length advantage into a better sprint performance (Washif & Pyne 2026). Physiologically, plyometric training increases the effectiveness of the stretch-shortening cycle, enhances tendon stiffness, and improves multi-muscular coordination; all of which are crucial for high-speed force production during the foot-ground contact phases of the sprint. These changes occur in terms of adaptations that are especially advantageous for longer-limbed sprinters, who need to produce higher angular velocities at the hip, knee and ankle joints to attain similar stride frequencies as sprinters with shorter limbs.

On the other hand, the control group, that remain engaged in general sprint training, not focused explicitly on plyometric training, do not improve as much. Although both their sprint times and CMJ height improve significantly (p=0.001 and p=0.011, respectively (Table 4). However, the changes are much smaller, with effect sizes (Cohen's d) of 0.48 and 0.33 respectively, versus 1.19 and 1.27 in the experimental group (Table 5). This indicates that sprint training alone has the capacity to induce adaptation in the control group who are already highly trained. Conversely, it is not specifically targeting the muscle, motor neuron and reflex pathways required for optimal explosive performance, which is essential to make full use of the biomechanical benefits of longer limbs. Our this result supports the contention of Pichardo et al. (2018) that as athletes grow older and their limbs get longer, they need to shift their training focus to power to maintain and advance their speed. It also supports the argument made by Liu et al. (2025) that the ability to generate horizontal force during sprinting is an adaptable attribute that requires a targeted training stimulus in addition to sole sprinting modality. The greater positive change in the experimental group implies that the 8-week treatment was not only additive, but also synergistic, so that the athletes could leverage on their already existing biomechanical and postural advantage.

The results of the reaction time are interesting. Though the main effect of time is significant, there is no significant interaction effect (see Table 3), ($F(1,30) = 0.62$, $p = 0.44$) and there is a significant main effect of time, which implies that all athletes would have improved their reaction time over the 8 weeks; most likely because they are familiarized with the starting procedure and their neural adaptation is generalized. This result is in line with earlier finding that movement reaction time is an independent variable, which is more related to cognitive and neural processing and less to limb length (Botha, 2023; Liuzzi et al., 2023). Concurrently, the within-group analyses indicate that there is a considerable improvement in the experimental group (p=0.007) but not in the control group (p=0.170). It suggests that plyometric training has a non-significant, but still a possible impact on reaction time (Chen et al., 2025).

Plyometric training involves increased neural activation and motor unit recruitment, which helps decrease the time from intention to action (Behm et al., 2024). This theory is somewhat supported by the findings of Harrison et al. (2019), who found that athletes with higher levels of explosive power often have shorter ground contact times and better neuromuscular recruitment, which could result in quicker start reactions. However, this notion needs to be examined further since previous studies Meredith and Marshall (2023) have demonstrated that reaction time and explosive power are not always related, especially in elite athletes, in whom reaction time is more related to attention and anticipation.

As for the impact of demographics and anthropometry is concerned, we found that leg length is a significant predictor of the sprint performance, however, both BMI and age are not significantly correlated to it. This may reflect the fact that the study sample is fairly homogenous in age and BMI as all participants are active and having normal-weight. The absence of a correlation with age likely reflects the fact that within the relative narrow age range of 14-17 years of age, chronological age is less relevant than biological maturity and training experience. This is in line with the findings of Vist Hagen et al. (2022), who stress upon the importance of biological maturity status in explaining variance in performance during adolescence.

Limitations and Future Research

Although this study is well-designed and robust in terms of its approach, it has some limitations. Since data on biological maturation status of the participants were not available, there exists possibility that differential growth rates between groups contributed to the observed interaction effects. The small sample size (N=32) while adequate to detect moderate-to-large effect sizes, may have limited our ability to detect smaller, yet potentially significant interaction effects, particularly for reaction time. Our study is exclusively limited to male adolescent sprinters from a specific territorial jurisdiction of Peshawar city, confining the scope of generalizability of its findings to females, other age groups, or athletes of other sports. Given the differences between males and females in terms of neuromuscular development and sprint mechanics, these findings need to be replicated in females. The 8-week duration of the intervention, although adequate to detect significant changes, does not allow insights into the long-term persistence of the effects or the possibility of further adaptation beyond the training intervention. Longitudinal research across one or, if possible, multiple competitive seasons would help understand the nature of these relationships as athletes pass through the adolescent growth spurt. Though 11% drop-out rate is small, but may have introduced some bias, although a post-hoc analysis revealed no difference in baseline values between drop-outs and those who completed the study. Furthermore, this study does not account for biological maturity, that is, in fact, a potential confounder in studies evaluating adolescent performance. Lack of control for biological maturation status was one of the main limitations of this study. Adolescents aged 14-17 normally pass through most vital phase of pubertal development when their peak growth velocity (PHV) appears. Rapid limb-lengthening is correlated to better sprint performance and increase in the explosive power, which are associated with rising level of testosterone in males, and these factors can independently improve sprint performance without any training intervention (Alvares et al., 2020). It would be useful for the future studies to replicate this work in a larger and more representative sample, including female athletes, different age groups and athletes of different performance levels. Using more advanced biomechanical measures, such as 3D motion capture which has the specialty to directly assess the stride length, stride frequency and joint angles, would offer greater insight into the mechanisms underlying the interaction between plyometric training and limb length to improve performance.

Conclusions

Findings of the study offer strong evidence that long legs are a major determinant of sprint performance, although only to the extent that they are accompanied by sufficient explosive power. The 8-week plyometric training program improved the explosive power of the young sprinters, enabling those with longer limbs to take advantage of their biomechanical edge and achieve faster sprint times. The results demonstrate mild association between the anthropometric variables and sprint performance meaning that these are not pre-determined and can be significantly improved through structured training. Reaction time developed with the training but without any anthropometric or structural involvement. Our study fills crucial research gap and advances the field by extending cross-sectional studies to show the combined importance of limb length and explosive power training through the 8-week intervention. This research lays the groundwork for more tailored approaches to training and development of sprint performance.

Implications

The present study has several practical implications for a diverse range of stakeholders. For coaches, the results provide guidance that scouting for talent should not be based only on limb length or stride frequency. Rather, a consideration of anthropometric measures in addition to measures of explosive force, such as the CMJ, is required. More significantly, the findings show that for athletes with longer limbs, a specific training strategy that includes plyometric exercises and RFD is vital to attain best sprinting potential. This shifts the coaching paradigm from a "one size fits all" to a more personalized and scientific approach of guiding athletes. Coaches associated with the adolescent athletes should include plyometric training as part of their sprint training program, especially during growth spurts when limb length is increasing.

For the athletes themselves, the study serves as a reminder that they need to not only be fast but they should also allocate a portion of their training time for the enhancement of their strength and explosive power following progressive plyometric training. It gives them insight about their physical potential that their structure can work as an asset in terms of performance in their pursuit of speed, depending solely on the nature of training motivating them to take a more active role in their training and development.

For training academies and educational institutions, especially in places like Peshawar where resources might be scarce, the study offers a cost-effective system for identifying and nurturing talent. Through the inclusion of basic field tests e.g., assessing leg length and performing a CMJ, in their testing batteries, they can better determine placement and training strategies for athletes. This may result in more effective resource allocation and improved athlete development. Additionally, the research highlights the need for a more integrated view of sports science and coaching practice, where coaches and scientists work together to employ scientific findings to training.

One future direction might be to include more refined measures of biological maturity such as age of peak height velocity [APHV]) to better examine the role of maturation status in performance. Additionally, it is also suggested that future research should include direct measures of rate of force development (RFD) and horizontal force, as these may offer a more sensitive measure of mechanisms driving performance enhancements instead of only CMJ height. Further, the lack of a BMI effect highlights that, in a population of "normal" weight athletes, other measures of body composition, such as lean muscle mass or limb segmental composition, may be better predictors of sprint performance. In the end, this study helps to build strong, evidence-based systems for developing sprinting talent in more remote regions and helps to translate global science to local practice.

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