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Peak Height Velocity (PHV) and Its Non-Significant Relationship with Physical Performance in Adolescent Soccer Athletes

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ABSTRACT

The purpose of the study. This study aimed to analyze the relationship between conditional capacities (agility, speed, aerobic capacity, and explosive strength) and somatic maturation—expressed as years from PHV—in a cohort of youth male soccer players.
Materials and methods. A quantitative, correlational, and cross-sectional design was employed. Seventeen male soccer players aged 14–15 years participated. Somatic maturation was assessed via anthropometric estimation of PHV. Physical performance was evaluated using the Andersen Test (aerobic capacity), 20 m sprint (linear speed), Illinois Agility Test, and horizontal jump (explosive strength). Tests were administered under standardized conditions across three sessions. Data analysis included descriptive statistics, Pearson correlation coefficients, and ANOVA using SPSS software.
Results. Descriptive findings indicated substantial variability in maturation (mean PHV = –0.89 ± 1.21 years), despite a homogenous chronological age. Correlation analyses revealed no statistically significant associations between PHV and the measured performance variables ($p > .05$). The strongest—but still non-significant—trend appeared between PHV and agility (Illinois test; $r = –0.319$), suggesting that more mature players may demonstrate slightly better change-of-direction ability. Overall, maturation did not directly predict aerobic performance, explosiveness, or speed in this sample.
Conclusions. Somatic maturation, expressed through PHV, did not significantly relate to physical performance indicators among the adolescent soccer players studied. The considerable variability in maturation reinforces the need for coaches to consider biological age rather than relying solely on chronological age when interpreting performance, prescribing training loads, and making talent selection decisions. These findings highlight the importance of individualized assessment and developmentally informed training in youth soccer contexts.

Keywords: somatic maturation; peak height velocity (PHV); youth soccer performance; biological maturity assessment; physical fitness indicators; agility and speed development.

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INTRODUCTION

Understanding biological maturation is fundamental to the physical development and performance trajectory of youth soccer players. During adolescence, athletes undergo substantial structural, hormonal, and functional changes that directly influence their conditional capacities and responses to training stimuli (Malina et al., 2004). These changes encompass rapid increases in stature, lean body mass, and muscle cross-sectional area, alongside surges in anabolic hormones such as testosterone and growth hormone, which collectively enhance power output, speed, and endurance capabilities. Somatic maturation—particularly the timing and tempo toward adulthood—varies widely among individuals of the same chronological age, producing observable differences in strength, coordination, speed, and neuromuscular efficiency (Lloyd & Oliver, 2012). This inter-individual variability arises from genetic, nutritional, and environmental factors, leading to heterogeneous developmental trajectories that can span several years within a single age group. This variability becomes especially relevant in youth soccer, where training demands and talent identification processes often fail to account for biological rather than chronological age, potentially disadvantaging late-maturing players who may appear less competitive despite comparable potential.

Existing literature underscores significant associations between maturational status and several physical performance domains. Prior studies have documented that physical capacities such as aerobic power, strength, agility, and speed demonstrate sensitive developmental periods aligned with growth and maturation (Gundersen et al., 2024; Tavakoly, 2025). For instance, research involving adolescent athletes has shown that bone age, a proxy for maturity, correlates with sprint speed, standing long jump, and endurance running in males, though less so in females (Gundersen et al., 2024). Research also indicates that coordination tends to

[abcde]Authors'Contribution: a-Study design; b-Data collection; c-Statistical analysis; d-Manuscript preparation; e-Funds collection.
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peak prior to the attainment of peak height velocity, whereas maximal strength increases after PHV due to greater muscle mass and hormonal changes (Granacher et al., 2011; Radnor et al., 2017). During the PHV period, which typically occurs around ages 13-15 in boys, athletes experience growth spurts that can temporarily impair coordination and relative power due to disproportionate limb lengthening, but post-PHV gains in muscle hypertrophy drive substantial improvements (Retzepis et al., 2025). Moreover, somatic maturation has been shown to influence technical and physical performance disparities among players within the same age category (Campa & Greco, 2022; Retzepis et al., 2025), often resulting in selection biases that favor early-maturing athletes who exhibit temporary advantages in size and strength. Several studies have utilized PHV as a reliable indicator of maturation status (Ginés et al., 2023; Mirwald et al., 2002; Towlson et al., 2020), helping practitioners better understand developmental stages relevant for long-term athletic development. Methods to estimate PHV, such as the Khamis-Roche protocol or predictive equations incorporating sitting height and leg length, allow for non-invasive classification into pre-, circa-, and post-PHV groups (Kalčíková & Přidalová, 2023; Towlson et al., 2020). However, the precise relationship between PHV and specific physical performance attributes, beyond these general trends, remains an area of ongoing investigation, with some studies suggesting a non-significant direct correlation in certain athletic cohorts (Kalčíková & Přidalová, 2023; Reis & Almeida, 2020; Sellami et al., 2024). For example, in soccer players aged 11-18, normative agility and ball-handling tests showed maturation-related differences, but predictors like sprinting and jumping abilities explained variance independently of PHV timing (Sellami et al., 2024).

Despite these insights, findings regarding the relationship between maturation and conditional capacities in youth soccer remain inconsistent. Some research suggests that early-maturing players exhibit superior performance in strength and speed-based tasks, but these advantages may diminish as athletes age (Aixa-Requena et al., 2025; Ginés et al., 2023). In elite youth academies, early maturers are overrepresented in male squads, linked to better anthropometrics and coach ratings, yet late maturers often sustain longer careers (Aixa-Requena et al., 2025; Ginés et al., 2023). Other studies report weak or non-significant associations between PHV and physical tests such as agility, sprinting, or endurance performance, highlighting the potential influence of confounding variables including technical proficiency, training exposure, and environmental factors (Maturana et al., 2017; Mujika et al., 2012). Tactical efficiency in small-sided games, for instance, varies more with skill level than PHV status in 14-year-olds (Reis & Almeida, 2020). Additionally, aerobic endurance appears to develop more independently of maturational status (Armstrong & Welsman, 2020; Kuswari et al., 2021), with peak VO2 often scaling allometrically with fat-free mass rather than chronological or biological age (Armstrong & Welsman, 2020). These discrepancies reveal the absence of consensus and suggest the need for further empirical evaluation in diverse youth soccer populations, particularly those from non-elite or regional clubs where resources for individualized monitoring are limited.

This inconsistency in the literature presents a notable research gap: the extent to which somatic maturation, expressed through PHV, directly influences conditional performance in adolescent soccer players remains unclear, particularly in smaller or developmental training contexts. Few investigations have employed multifaceted test batteries—encompassing agility (e.g., change-of-direction speed), linear speed (e.g., 20-30m sprints), aerobic capacity (e.g., Yo-Yo Intermittent Recovery Test), and explosive strength (e.g., countermovement jumps)—while statistically controlling for inter-individual variation via covariates like training history and body composition. Furthermore, limited studies have investigated multifaceted physical tests simultaneously while controlling for the wide inter-individual variation characteristic of early-to-mid adolescence, such as the transient coordination deficits during PHV (Retzepis et al., 2025). Addressing this gap is critical not only for scientific clarity but also for practical applications in training individualization, injury prevention, and talent development. For example, maturity-matched "bio-banding" formats have shown promise in reducing biases and enhancing skill development (Towlson et al., 2020).

Given these considerations, further investigation is warranted to clarify whether maturation status substantially contributes to differences in agility, speed, aerobic capacity, or explosive strength among young soccer players. A clearer understanding would help coaches design age-appropriate training loads, reduce misclassification in talent identification, and minimize injury risk during accelerated growth phases (Gonaus et al., 2023; Tavakoly, 2025). Recent trends indicate decade-long improvements in sprint and agility among elite youth, underscoring the interplay of maturation with training evolution (Gonaus et al., 2023), yet non-significant PHV effects in specific cohorts suggest context-specific factors dominate (Sellami et al., 2024).

Therefore, the objective of this study was to analyze the relationship between conditional capacities and somatic maturation in a group of youth soccer players, using PHV as a marker of biological maturity. This investigation aims to provide evidence-based insights that support more equitable and developmentally aligned training and evaluation practices in youth soccer, ultimately fostering long-term player retention and success.

MATERIALS AND METHODS

Participants

The sample consisted of 17 male soccer players, aged 14-15 years, with at least one year of training experience. The sampling was non-probabilistic by convenience. Informed consent was given by the researcher and exposed to the players, in accordance with the ethical principles of the Declaration of Helsinki.

Study Organization: Quantitative Analysis

A quantitative, correlational and comparative cross-sectional study was carried out in order to evaluate physical variables related to physical condition and maturation in child soccer players. The design facilitated the characterization of physical performance according to the maturity level, establishing relationships between the different physical capacities evaluated.

Test and Measurement Procedures

The tests were performed in a period of three consecutive sessions, under normal environmental conditions and based on standardized protocols. Prior to the application of the tests, the players performed a general warm-up for 15 minutes, followed by a specific mobility test.

Table 1. Summary of Testing Procedures and Measurement Protocols

Test / Procedure	Description	Measurement Output
Peak Height Velocity (PHV)	Somatic maturation was estimated by calculating the number of years from the predicted peak height velocity using anthropometric measures: height, weight, sitting height, and chronological age.	Maturity offset (years from PHV)
20 m Speed Test	Acceleration and linear speed measured through a 20-meter sprint. Each player performed two trials, with the fastest time recorded.	Sprint time (seconds)
Andersen Test	Aerobic capacity assessed through repeated 15-second run + 15-second rest intervals for 10 minutes. Total distance used to estimate VO_2 max with the formula: VO_2 max = 18.38 + 0.033 × distance – 5.92 × sex.	Total distance (m) and estimated VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)
Illinois Agility Test	Agility assessed through a standardized course involving accelerations, directional changes, and lateral movements. Two attempts were performed; best time recorded.	Completion time (seconds)
Horizontal Jump Test	Lower-limb explosive power measured using a standing long jump without run-up. Best distance from three attempts recorded.	Jump distance (cm)

Statistical Analysis

Data were analyzed by descriptive statistics and Pearson's correlation was applied to explore the relationship between maturation and physical abilities and ANOVA analysis of variance, this was done using SPSS statistical software.

Ethical Considerations

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki and received ethical approval from the Institutional Review Board (IRB) / Ethics Committee of Caribbean University Corporation (Approval No.: CUC/EC/no. 621-2025). Written informed consent was obtained from parents or legal guardians, and verbal assent was obtained from all participants prior to data collection. Participation was voluntary, and all players were informed of their right to withdraw at any time without penalty. All procedures were non-invasive and posed minimal risk, and confidentiality of participant information was ensured through anonymization and secure data handling

RESULTS

The results of the following work evaluated the relationship between maturation status and performance in different tests in a sample of 17 soccer players.

Table 2. Descriptive statistics for the basic variables of the subjects under study

	Age (years)	Weigth (kg)	Heigth (cm)
N	17	17	17
Missing	0	0	0
Mean	14.4	53.5	168
Median	14.5	52.2	172
Standard Deviation	0.593	8.10	8.13
Minimum	13.3	38.6	148
Maximum	15.1	68.0	177

The sample was composed of 17 soccer players with an average age of 14.4 ± 0.59 years, with an average weight of 53.5 ± 8.10 kg and an average height of 168.0 ± 8.13 cm. Despite the fact that the chronological age was homogeneous, a high dispersion in weight and height could be observed, which translates into disparities in the maturation of the players.

Table 3. Descriptive statistics of the physical fitness tests of the study group

	PHV	Test de Andersen (m)	Salto horizontal (cm)	Vel 20m (seg)	Test Illinois (seg)
Minimum	-2,5	972,0	152,0	371,0	168,0
Maximum	1,8	1220,0	237,0	450,0	1605,0
Median	-,88	1133,8	196,2	398,4	1456,5
Standard Deviation	1,2	57,36	23,5	20,2	333,5

Table 2 shows the descriptive statistics of the variables studied in the sample of 17 players aged 14-15 years, these variables include the PHV and conditional abilities such as aerobic endurance (Andersen test), explosive strength in lower limbs (horizontal jump), linear speed (speed in 20m) and agility (Illinois test). On the side of somatic maturation (PHV) the average value was -0.89 ± 1.21 years, indicating that the players have not yet reached their peak growth rate, the high standard deviation value means an important variability in the maturational level, such variability could have direct implications on the response to the training load and performance. As for the aerobic capacity, by means of the Andersen test, the mean was 1133.88 ± 57.36 m, with a range that had a variation between 972 and 1220m, values that reflect a moderate aerobic level, something estimated in players at those ages, this capacity is less dependent in relation to maturation and is more influenced by training, which could be the explanation for the lower dispersion.The explosive strength measured by means of the horizontal jump test had a mean value of 196.29 ± 23.51 cm, with test results between 152 and 237 cm, which shows statistical differences in explosive strength that could be attributed to the maturation stage. On the other hand, the 20m speed test showed values of 3.98 ± 0.20 sec, which shows a consistency in the results, this means a homogeneity in the capacity. Finally, the Illinois test had a mean of 14.57 ± 0.33 sec, with a range of 14.56 to 16.80 seconds, a small variability was observed, which could be related to the motor coordination and the efficiency of the neuromuscular system, capacities that evolve with the development of the nervous system.

Table 4. Pearson Correlation Matrix Between PHV and Physical Performance Variables

Variables	PHV	Andersen (m)	VO_2 max (ml·kg⁻¹·min⁻¹)	Illinois Agility (s)	20 m Speed (s)	Horizontal Jump (cm)
PHV	—	—	—	—	—	—
Andersen (m)	r = –0.017 p = 0.950 df = 15	—	—	—	—	—
VO_2 max	r = –0.017 p = 0.950 df = 15	r = 1.000*** p < 0.001 df = 15	—	—	—	—
Illinois Agility (s)	r = –0.319 p = 0.213 df = 15	r = –0.053 p = 0.839 df = 15	r = –0.053 p = 0.839 df = 15	—	—	—
20 m Speed (s)	r = –0.107 p = 0.682 df = 15	r = 0.001 p = 0.996 df = 15	r = 0.001 p = 0.996 df = 15	r = 0.582* p = 0.014 df = 15	—	—
Horizontal Jump (cm)	r = 0.132 p = 0.613 df = 15	r = 0.049 p = 0.853 df = 15	r = 0.049 p = 0.853 df = 15	r = 0.002 p = 0.994 df = 15	r = 0.106 p = 0.687 df = 15	—

Notes:r = Pearson correlation coefficient; df = degrees of freedom; *p < .05 = significant correlation.
***perfect correlation due to derived VO_2 max formula from Andersen test

The analysis of bivariate correlations did not show statistical relationships between PHV and the rest of the physical variables evaluated, which suggests that maturation evaluated by means of time relative to peak growth velocity was not a direct indicator of conditional performance in the sample evaluated (p>.05). The most relevant association was between the PHV and the agility test (r=-0.319, p=0.213), which indicates a negative and moderate tendency, although not significant, it could indicate that the more mature players obtain better changes of direction.
Among the variables analyzed the correlations between the PHV and the physical tests are presented the Pearson coefficient (R), degrees of freedom (gl) and statistical values (p-value) the variables are analyzed with main results, the PHV states a low correlation with Andersen (R=0.017) (P-value=0.950) with the VO2 MAX (R=0.017) (p-value=0.950) with horizontal jump (R=0.132) (p-value=0.613).

DISCUSSION

The present study examined the relationship between somatic maturation—operationalized through Peak Height Velocity (PHV)—and various physical performance indicators in young soccer players. Overall, the findings indicate an absence of statistically significant correlations between maturation status and performance in aerobic capacity, explosive strength, linear speed, or agility, although a moderate but non-significant trend emerged between PHV and agility. These results suggest that biological maturation, as measured through PHV, does not uniformly translate into superior conditional performance across early and mid-adolescence.

When interpreted in the context of prior research, the findings present both convergences and divergences. The moderate tendency between PHV and agility aligns conceptually with Pichardo et al., (2019) and Sellami et al., (2024) Youth Physical Development Model, which posits that neurocognitive efficiency and motor coordination often improve as maturation progresses. However, the lack of significant associations contradicts earlier work reporting maturational advantages in speed, strength, and agility among early-maturing athletes (Antonijević et al., 2023; Gundersen et al., 2024). Similarly, the independence observed between PHV and aerobic performance supports previous evidence showing that endurance is more sensitive to training stimulus than to maturational tempo (Eskandarifard et al., 2021; Tingelstad et al., 2023). The non-associations involving lower-limb explosive strength align with (Granacher et al., 2011), who emphasize that different strength attributes (e.g., reactive strength vs. horizontal propulsion) exhibit distinct developmental trajectories that are not solely maturation-driven. This further underscores the necessity of considering the multifaceted physiological and biomechanical changes occurring during adolescence, rather than solely attributing performance differences to maturational status (Tavakoly, 2025). Indeed, the present study aligns with findings that somatic maturation, as defined by age at PHV, accounts for limited variance in physical performance metrics such as strength, speed, acceleration, and vertical jump (Konarski et al., 2024).

The implications of these findings carry meaningful ramifications for training methodology and talent identification. First, the absence of clear maturational advantages underscores the risk of overvaluing early developers in selection processes. Systems that rely predominantly on physical profiles may inadvertently disadvantage late-maturing players whose long-term potential may be equal or superior (Sweeney et al., 2023). Second, the variability in PHV values within a chronologically homogeneous group reinforces the necessity for individualized training prescription, as advocated by the LTAD framework (Helsen et al., 2021). Tailoring training loads to biological age may reduce injury risk, enhance motor learning windows, and facilitate more equitable developmental trajectories. Third, the modest trend between maturation and agility suggests that coaches should place greater emphasis on neuromuscular and coordination-focused interventions during pre- and mid-PHV stages, which represent critical windows of trainability (Lloyd et al., 2013; Thieschäfer & Büsch, 2022).

Despite these contributions, several limitations should be acknowledged. The small sample size (n = 17) likely reduced the statistical power to detect meaningful relationships, especially given the high inter-individual variability in maturation status. Additionally, the cross-sectional design does not allow causal inference or examination of dynamic developmental changes across maturation stages. The reliance on field-based performance tests, while practical, may not capture more nuanced biomechanical or neuromuscular mechanisms underlying developmental differences. Furthermore, intergroup variability—particularly within the pre-PHV subgroup—may have masked potential patterns that longitudinal approaches could clarify. Future investigations should incorporate larger samples, longitudinal monitoring, and complementary physiological or biomechanical assessments to elucidate more precisely how maturation interacts with performance variables across developmental periods.

CONCLUSION

This study provides a clear and integrative understanding of the relationship between somatic maturation—expressed through Peak Height Velocity (PHV)—and physical performance in adolescent soccer players. Despite theoretical expectations and prior evidence suggesting maturational advantages in speed, strength, and agility, the present findings consistently demonstrate that PHV did not exhibit statistically significant correlations with aerobic capacity, explosive strength, linear speed, or agility across the tested cohort. These results offer closure to the initial hypotheses by indicating that biological maturation, while influential in developmental physiology, does not uniformly determine conditional performance outcomes in early to mid-adolescence.

The study reinforces key concepts discussed throughout the paper: (1) maturation among same-age players is highly heterogeneous; (2) conditional abilities are shaped by a multifactorial interaction of neuromuscular, technical, environmental, and training-related factors; and (3) chronological age is insufficient for interpreting physical potential or prescribing equitable training loads. The moderate, non-significant tendency between PHV and agility aligns partially with the theoretical framework presented in the Introduction, yet the overall lack of association across variables contributes valuable nuance to current debates on maturation-driven performance differences.

Importantly, these findings highlight the practical relevance for coaches, practitioners, and youth development systems. The results underscore the need for individualized training programs, maturity-informed evaluation strategies, and more cautious talent identification processes that avoid overemphasizing early physical advantages. Such insights may lead to more inclusive developmental pathways and support long-term athlete retention and success.

Given the study's limitations—particularly the small sample size and cross-sectional design—future investigations should consider longitudinal monitoring of growth trajectories, larger and more diverse samples, and multimodal assessments integrating biomechanical and hormonal indicators. To strengthen subsequent research in this domain, we encourage authors and practitioners to contribute suggestions, methodological refinements, or contextual perspectives that may enhance the accuracy and applicability of maturity-based performance profiling in youth soccer.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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