International Journal of Physical Education, Sports and Health 2025; 12(2): 84-88

P-ISSN: 2394-1685
E-ISSN: 2394-1693
Impact Factor (RJIF): 5.38
IJPESH 2025; 12(2): 84-88

https://www.kheljournal.com
Received: 20-01-2025
Accepted: 24-02-2025

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A comparative study on the selected motor fitness components and soccer skills of adolescent players of the hilly and plain region

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DOI: https://www.doi.org/10.22271/kheljournal.2025.v12.i2b.3701

Abstract
Football performance depends on motor fitness and technical skills, shaped by environmental and training conditions. This study compares the motor fitness components and soccer skills of adolescent football players from hilly and plain regions. A total of 80 male footballers (40 from Kalimpong and 40 from Kolkata), aged 12-14 years, participated. Motor fitness attributes, including speed, agility, power, balance, and coordination, were assessed using standardized tests, while soccer-specific skills were evaluated through the SAI Soccer Skill Test. Results showed that hilly-region players outperformed in speed, agility, balance, kicking accuracy, and juggling, whereas plain-region players exhibited superior power and coordination. These differences are attributed to environmental factors affecting training conditions, terrain, and physiological adaptations. Independent t-test analysis revealed significant differences ($p < 0.05$) in most parameters, except coordination. The study suggests that training programs should be region-specific, focusing on strength and plyometric training for hilly players and endurance conditioning for plain-region players. Findings offer insights for talent identification and training optimization based on geographical influences. Future research should investigate long-term adaptations and include biomechanical assessments to refine training strategies and enhance player development.

Keywords: Motor fitness, soccer skills, adolescent footballers, hilly region, plain region, training adaptation, environmental influence

Introduction
Football is a world-renowned sport that calls for great physical fitness, technical proficiency, and tactical knowledge. Unlike most other sports, football needs a blend of endurance, agility, speed, strength, and flexibility, all of which are vital in influencing an athlete's performance on the field (Stølen *et al*., 2005) [21]. Moreover, technical skills like dribbling, passing, shooting, ball control, and tactical decision-making play a role in the effectiveness of a player in both individual and team play (Reilly *et al*., 2000) [16]. The acquisition of these traits is affected by various factors, such as genetics, training methods, environmental factors, and availability of sports facilities (Mandal, 2023) [13]. Of these, the geographical location of a sportsperson's training facility plays a key role in affecting their physical conditioning and skill acquisition (Singh & Singh, 2016) [20]. Players from various geographical locations tend to have unique physical and technical attributes based on differences in terrain, altitude, climate, and training conditions. Players from mountainous areas are naturally adapted to high-altitude conditions, where oxygen is scarce and the ground is typically rough and uneven (Fjørtoft, 2004) [6]. Training under such conditions imposes a higher burden on the respiratory and cardiovascular systems, resulting in physiological adaptations like enhanced lung capacity, better oxygen utilization, and increased endurance (Harrison *et al*., 2015) [9]. In addition, walking, running, and training on sloping terrain demand higher muscular strength, especially in the lower limbs, which could be responsible for better leg strength and endurance in players from hilly areas (Arafat *et al*., 2020) [1].
In contrast, players from flat areas train in comparatively stable and predictable conditions, which can be beneficial in terms of speed, agility, and technical skill development.

Flat landscapes enable more controlled movement and coordination during training exercises, resulting in enhanced agility and acceleration (Rural & Kushinagar, 2024) [18]. In addition, plains players might enjoy greater access to organized training centers, such as well-manicured football pitches, coaching schools, and sports science services, which might lead to greater technical competence in dribbling, passing, and shooting. These geographical differences imply that hilly and plain players might acquire different strengths and weaknesses in motor fitness and soccer skills. However, no in-depth studies have been conducted that systematically compare such differences in adolescent footballers (Sacchetti *et al*., 2012) [19]. Although previous research has addressed the effects of altitude training on endurance and aerobic capacity, relatively little attention has been paid to the effects of environmental factors on general motor fitness and technical skill acquisition in young footballers. Knowledge of motor fitness and soccer skill differences between players from plain and hilly areas is critical to planning region-specific training programs (Khoo & Al-Shamli, 2012) [10]. It might not be possible to train footballers uniformly to achieve optimal performance of players with different geographical backgrounds. By recognizing the abilities and weaknesses of players according to their training setting, coaches and sports scientists can construct specific training practices that improve comprehensive athletic development. For instance, players from hills will need supplemental training to augment speed and agility, whereas players from plains can be conditioned using endurance-based methods to increase stamina.

This research explores the impact of environmental conditions on the physical and technical attributes of adolescent footballers from hilly and plain regions, aiming to provide valuable insights for talent identification and development programs. By conducting a comparative analysis of motor fitness components such as speed, agility, endurance, strength, and flexibility, along with soccer skills like dribbling, passing, and shot accuracy, the study seeks to identify regional variations and their influence on overall performance. Understanding these differences will enable football schools and coaching institutions to design specialized training programs that cater to the specific needs of players based on their geographical backgrounds. Additionally, the findings will help bridge the knowledge gap regarding how environmental factors shape young athletes' abilities, ultimately contributing to more effective scouting, recruitment, and training interventions for player development and performance enhancement in football.

Objective of the study

The primary objective of this study is to conduct a comparative analysis of the selected motor fitness components and soccer skills of adolescent football players from hilly and plain regions. The specific objectives are as follows:

1) To compare motor fitness components like speed, agility, power, balance, and coordination between hilly and plain region players.
2) To analyze soccer skills such as dribbling, passing, kicking accuracy, juggling, and ball control in both groups.
3) To examine the impact of environmental factors like terrain, altitude, and climate on players' fitness and skills.
4) To provide training recommendations for improving performance based on regional differences.

Materials and Methods

This study aimed to compare adolescent football players' selected motor fitness components and soccer skills from hilly and plain regions. The investigation involved assessing key motor fitness attributes, including speed, agility, power, balance, and coordination, alongside soccer-specific skills using the SAI Soccer Skill Test. The participants were selected from Kalimpong (hilly region) and Kolkata (plain region) in West Bengal. Standardized protocols were followed for data collection, ensuring accuracy and reliability.

Study design

A comparative research design was employed to analyze motor fitness and soccer skills differences between adolescent players from hilly and plain regions. A total of 80 participants (N=80), aged 12-14 years, were selected for the study. The sample was equally divided, with participants (N=40) from Kalimpong (hilly region) and participants (N=40) from Kolkata (plain region). The selection criteria included adolescent male players actively engaged in football training, with at least two years of playing experience at the school or club level. Participants with any history of injuries or medical conditions affecting performance were excluded from the study.

Instrumentation

To evaluate motor fitness, five components were assessed using standardized field-based tests:

- **Speed:** Measured using a 50-meter sprint test, recorded in seconds.
- **Agility:** Assessed using the 4×10m Shuttle Run Test, which evaluates directional changes and movement control.
- **Power:** Evaluated through the Standing Broad Jump Test, measuring explosive lower-body strength.
- **Balance:** Tested using the Stork Stand Balance Test, which determines static balance ability.
- **Coordination:** Assessed using an Eye-Foot Coordination Test, which evaluates an individual's ability to control the ball using both visual perception and foot movement precision.

The SAI Soccer Skill Test (1992) was used to evaluate fundamental soccer abilities, including 30-meter running with the ball, kicking accuracy, and juggling. This test, widely recognized for assessing technical skills, measures speed and control in seconds for the running test, evaluates precision through the number of successful kicks, and assesses ball control by counting successful juggles within a set number of attempts. The test was conducted under uniform conditions to ensure fairness, minimizing external variability for a reliable comparison between groups.

Statistical tools

Descriptive statistics, including mean and standard deviation, were used to summarize the data. An independent t-test was performed to determine the significance of differences between the hilly and plain region groups for each motor fitness component and soccer skill parameter. A significance level of $p < 0.05$ was set for statistical analysis. Data processing and analysis were conducted using SPSS version 26 to ensure accuracy and reliability. The results were further interpreted to understand the impact of geographical differences on adolescent football players' motor fitness and skill performance.

Results

To achieve the study's purpose, data were collected and analyzed using statistical techniques, and the results are presented in the following tables.

Table 1: Descriptive statistics of selected motor fitness components and soccer skills of adolescent players from hilly and plain regions

Group statistics					
	Groups	**N**	**Mean**	**Std. deviation**	**Std. error mean**
Speed	Hilly	40	8.00	.48	.08
	Plains	40	9.27	.97	.15
Agility	Hilly	40	10.03	.47	.07
	Plains	40	11.62	1.13	.18
Power	Hilly	40	1.75	.22	.04
	Plains	40	1.37	.21	.03
Balance	Hilly	40	7.90	3.44	.54
	Plains	40	5.78	2.94	.46
Coordination	Hilly	40	7.00	1.00	.16
	Plains	40	7.64	2.36	.37
30m running with the ball	Hilly	40	7.07	.91	.14
	Plains	40	7.96	.59	.09
Kicking accuracy	Hilly	40	6.10	2.02	.32
	Plains	40	3.65	2.03	.32
Juggling	Hilly	40	30.00	27.34	4.32
	Plains	40	8.37	4.09	.65

The descriptive statistics table 1 presents a comparative analysis of selected motor fitness components and soccer skills of adolescent players from hilly and plain regions. The results reveal notable differences between the two groups across various performance parameters. In terms of speed, players from the hilly region recorded a lower mean time (8.00 seconds) compared to those from the plains (9.27 seconds), indicating better sprinting ability. Similarly, in agility, hilly-region players exhibited superior performance with a mean of 10.03 seconds, while their plains counterparts took longer (11.62 seconds), suggesting quicker directional changes among hilly-region players. For power, however, players from the plains (1.37) showed lower values than those from the hilly region (1.75), which could be attributed to differences in muscle strength and explosive capacity. In balance, hilly players demonstrated a higher mean score (7.90) compared to plains players (5.78), implying better stability and postural control. Regarding coordination, the hilly group had a slightly lower mean score (7.00) than the plains group (7.64), though the standard deviation was notably higher in the plains group, indicating greater variability in performance. In the 30 m running with the ball test, hilly players (7.07 seconds) performed better than those from the plains (7.96 seconds), highlighting their enhanced dribbling speed. A significant contrast was observed in kicking accuracy, where hilly players (6.10) outperformed plains players (3.65), suggesting superior precision in ball control. Similarly, in juggling, hilly-region players demonstrated exceptional proficiency (30.00), whereas plains players had a much lower mean score (8.37), reflecting better ball mastery among hilly players. Overall, the findings indicate that adolescent football players from hilly regions tend to excel in speed, agility, balance, kicking accuracy, and juggling, whereas those from the plains show relatively lower variability in coordination and power. These differences may stem from geographical and environmental influences, impacting the motor fitness and technical skill development of players from different terrains.

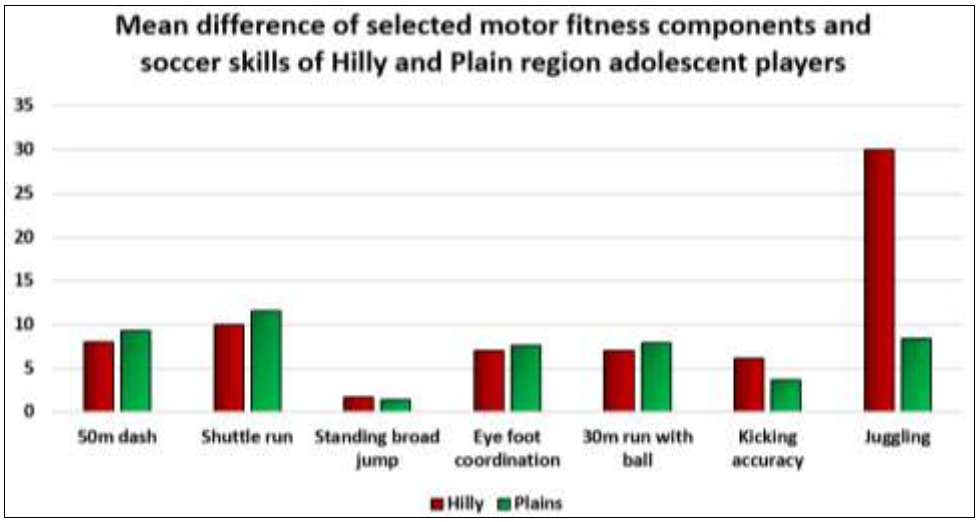

Fig 1: Graphical representation of mean difference of selected motor fitness components and soccer skills of adolescent players from hilly and plain regions

Table 2: Significance of differences between selected motor fitness components and soccer skills of adolescent players of the hilly and plain regions

		Levene's test for equality of variances		**t-test for equality of means**		
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**
Speed	Equal variances assumed	9.975	.002	7.420	78	.000*
Agility	Equal variances assumed	22.974	.000	8.227	78	.000*
Power	Equal variances assumed	1.153	.286	7.391	78	.000*
Balance	Equal variances assumed	1.492	.226	2.958	78	.004*
Coordination	Equal variances assumed	23.634	.000	1.592	78	.115
30m running with the ball	Equal variances assumed	3.974	.050	5.078	78	.000*
Kicking accuracy	Equal variances assumed	.079	.779	5.404	78	.000*
Juggling	Equal variances assumed	30.386	.000	4.947	78	.000*

*Significance at 0.05 level of confidence

Table 2 presents the results of independent samples t-tests assessing differences between two groups across selected motor fitness components and soccer skills, including Speed, Agility, Power, Balance, Coordination, 30m Running with the Ball, Kicking Accuracy, and Juggling. Levene's Test for Equality of Variances determines whether the assumption of equal variances holds, with a significant result (p <.05) indicating unequal variances. For Speed (p =.002), Agility (p<.001), Coordination (p<.001), 30 m Running with the Ball (p =.050), and Juggling (p<.001), Levene's test was significant, suggesting unequal variances, whereas for Power (p =.286), Balance (p =.226), and Kicking Accuracy (p =.779), variances were equal (p>.05). The t-tests reveal significant differences in Speed (p<.001), Agility (p<.001), Power (p<.001), Balance (p =.004), 30 m Running with the Ball (p<.001), Kicking Accuracy (p<.001), and Juggling (p<.001) between groups, whereas no significant difference was found in Coordination (p =.115). These results indicate that regional variations may influence motor fitness and soccer skill development among adolescent soccer players.

Discussion

The findings of this study underscore the distinct differences in motor fitness attributes and soccer skills between adolescent footballers from hilly and plain regions, emphasizing the significant role of environmental factors in shaping athletic performance. Players from hilly regions demonstrated superior endurance, agility, balance, and kicking accuracy, which align with previous research highlighting the impact of geographical terrain on physiological and biomechanical adaptations (Chowdhuri *et al*., 2002) [4]. Training in high-altitude, rugged landscapes enhances aerobic efficiency, movement adaptability, and stamina, providing these athletes with a natural advantage (Lundby & Robach, 2016; Mujika *et al*., 2019) [12, 15]. Additionally, their improved sprinting ability and agility can be attributed to neuromuscular engagement necessitated by frequent elevation changes and uneven surfaces, leading to superior reaction speed and movement efficiency (Bailey *et al*., 2001; Millet *et al*., 2010) [3, 14]. Conversely, footballers from plain regions exhibited greater lower-body power, as reflected in their superior standing broad jump scores. The stable and structured training environments in these regions likely facilitate the development of explosive strength, with access to resistance training and plyometric drills further enhancing sprint performance and shot accuracy (Rodríguez-Rosell *et al*., 2017; Los Arcos *et al*., 2014) [17, 11].

Technical skill execution also varied between the two groups, with hilly-region players excelling in dribbling speed, kicking precision, and juggling ability. The dynamic and unpredictable training environments they experience contribute to heightened proprioception, foot-eye coordination, and adaptability under pressure, aligning with research on ecological constraints and skill acquisition (Millet *et al*., 2010) [14]. In contrast, plain-region players exhibited marginally better coordination, likely due to structured training regimens emphasizing repetitive technical drills. While controlled environments enhance consistency in skill execution, they may not fully replicate the adaptability required in match situations, where exposure to irregular playing surfaces can improve real-time decision-making and motor control (Hamlin *et al*., 2010) [8]. These findings highlight the necessity of tailored training interventions, where hilly-region players incorporate strength and plyometric exercises to enhance explosive power, while plain-region players engage in endurance conditioning and agility drills to improve stamina and reactive movement (Gabbett, 2013) [7].

Beyond performance optimization, these insights hold valuable implications for talent identification and scouting processes. Recognizing the influence of geographical training backgrounds allows for more informed athlete selection, ensuring assessments account for environmental factors shaping player development. Understanding an athlete's adaptability to varied playing conditions is crucial for long-term performance sustainability (Dollman, 2018) [5]. Additionally, future research should explore longitudinal training interventions to mitigate regional disparities and optimize player development. Incorporating advanced motion capture technologies and physiological monitoring could provide deeper insights into biomechanical and metabolic adaptations, further enhancing coaching strategies and sports science applications (Arcos *et al*., 2014) [2]. This study expands the discourse on environmental influences in football performance, encouraging a more comprehensive approach to athlete development.

Conclusions

This research presents a comparative assessment of selected motor fitness attributes and soccer skills among adolescent football players from hilly and plain regions, highlighting significant differences in their performance. Players from hilly areas exhibited superior speed, agility, balance, kicking accuracy, and juggling, whereas those from the plains outperformed in power and coordination. These variations can be attributed to the unique environmental and geographical conditions that shape training adaptations, ultimately influencing athletes' physical and technical development. The findings underscore the importance of region-specific training approaches to maximize young footballers' athletic potential. Tailored training programs should be implemented to address the distinct strengths and areas for improvement of players based on their geographical backgrounds. For instance, footballers from hilly regions may benefit from power and strength-focused exercises, while those from the plains should integrate endurance and agility-oriented training into their routines.

In addition to its training implications, this study provides valuable insights into talent identification and scouting strategies, emphasizing the need to consider environmental influences when assessing players' potential. Recruitment programs should take into account how regional factors contribute to athletic performance, allowing for a more effective selection process. While this study offers a detailed comparison, future research should broaden its scope by including a larger sample size and conducting longitudinal studies to enhance the reliability of the findings. Further investigations incorporating biomechanical and physiological assessments could provide a deeper understanding of the performance variations among players from different geographical backgrounds. The outcomes of this research contribute to the field of sports science and offer practical applications for coaches, trainers, and professionals involved in youth football development.

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