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Research Article

Biomechanical and Anthropometric Determinants of Motor Fitness Performance: A Comparative Cross-Regional Analysis of Urban, Semi-Urban, and Tribal Handball Players

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Abstract

This paper will explore biomechanical and anthropometric factors that determine the performance of motor fitness in the handball players of urban, semi and tribal areas. The comparative cross-sectional design was used in the study, which involved 90 participants whose age ranged between 18 and 25 years and was evenly distributed in the three categories. The anthropometric measurements involving height, weight, body mass index, arm span and leg length were discussed in association with biomechanical measurements of a jumping force, stride length and joint angles with motor fitness measures of speed, agility, strength, endurance and flexibility. The data indicate substantial differences based on the region and that the urban players have better anthropometric benefits and upper-body strength, whereas the tribal players were more successful in speed, agility, endurance, and flexibility. Semi-urban players were performing fairly generally in most of the variables. Correlation and regression models have revealed that jump force, stride length, height and arm span are the key predictors of the motor fitness performance, with a significant percentage of variance in the performance. The analysis points out that the structural attributes, as well as the movement efficiency, have a significant effect on athletic performance. Moreover, the existing differences between different regions depending on the availability of training, the essence of lifestyle and the environment have a very important impact on the achievement of fitness. In order to optimise performance and talent in handball, the results highlight the necessity of considering approach and longer region-based training interventions.

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KEYWORDS: Biomechanics; Anthropometry; Motor Fitness; Handball Performance; Regional Comparison; Athletic Performance; Sports Science; Talent Identification

1. INTRODUCTION

1.1 Background of the Study

Motor fitness refers to a multidimensional construct, including speed, strength, endurance, agility, flexibility, as well as coordination, which all jointly influence the performance of the athletes in dynamic sports, like handball (Bompa and Buzzichelli, 2020). Motor fitness during high-intensity intermittent sports is a condition of not only training but also the inherent biomechanical and anthropometric factors that determine the efficiency and performance output (Pojskic et al., 2020). Handball is a game that involves fast accelerations, directional shifts, jump, and throws, which need optimal biomechanical performance to reach the highest levels of performance with a minimum number of injuries (Wagner et al., 2021).

Production of force, leverage systems and movement patterns are major decision factors in determining biomechanical efficiency in handball. The coordination of the kinetic chains helps to improve the velocity of the throws and the jumping capacity, whereas inadequate mechanics can restrain the performance and raise the fatigue (Hermassi et al., 2020). Likewise, anthropometric parameters, e.g., height, limb length, body mass index (BMI), and body composition, also play a major role in performance because of the positive impact they have on reach, stride length, and mechanical advantage (Matthys et al., 2021).

Also, asserting regional variations in sports development, especially between urban, semi-urban, and tribal groups, is of utmost importance to determining the athletic potential. Infrastructure, coaches, and nutrition can frequently favour urban athletes, and there are always physical advantages related to tribal athletes because of the lifestyle and adaptation to the environment, but the exercise assists are not yet structured (Singh et al., 2022). Such variations require a comparative study in order to be able to interpret the interplay of biomechanical and anthropometric factors with regional conditions to determine their effect on motor fitness performance.

1.2 Rationale of the Study.

Although sports science in India is gaining increasing attention, the comparative level of analysis of biomechanical and anthropometric predictors of specific regional groups of handball players is still missing (Kumar and Yadav, 2021). The vast majority of the current studies are involved either in separate physical characteristics or, in the case of elite athletes, thus disregarding regional differences and variations at the grassroots level.

Since biomechanical efficiency and anthropometric characteristics are interrelated, it is important to know how these factors interact and which anthropometric factors can be used to predict important variables in motor fitness performance. These understandings can add to evidence-based talent recognition, helping coaches to identify possible athletes who would not be identified by traditional selection protocols (Gorostiaga et al., 2020).

Besides, this study has practical implications in the development of regionally-based training programs. Strengths and weaknesses peculiar to urban, semi-urban, and tribal players can be determined and, using them, special interventions are developed, which are then implemented to improve performance results and correct existing differences in sports development (Sharma et al., 2023).

1.3 Problem Statement

There is limited empirical evidence examining how biomechanical and anthropometric factors vary across different regional groups and how these variations influence motor fitness performance among handball players (Rathore et al., 2022). This gap restricts the development of optimized training strategies and equitable talent identification systems.

1.4 OBJECTIVES OF THE STUDY

- To analyse anthropometric profiles of handball players across urban, semi-urban, and tribal regions
- To examine biomechanical determinants affecting motor fitness performance
- To compare motor fitness performance among regional groups
- To establish relationships between anthropometric, biomechanical, and performance variables

1.5 Research Questions / Hypotheses

H1: Significant differences exist in anthropometric variables across regions (Kumar & Yadav, 2021)
H2: Biomechanical factors significantly influence motor fitness performance (Hermassi et al., 2020)
H3: Tribal players demonstrate distinct physical advantages and/or disadvantages due to environmental and lifestyle factors (Singh et al., 2022)

2. REVIEW OF LITERATURE

2.1 Anthropometric Factors in Sports Performance

Basic anthropometrical variables like body weight, height and level of body mass index (BMI), limb length and body composition are inalienable predictors of athletic performance in most sports activities. Cases involving handball, taller and sufficiently armed players with ideal body make up are likely to have mechanical edge in shooting, blocking or distance to defend (Matthys et al., 2021). Research shows that lean muscle mass has a positive effect on strength and power production, and excess body fat may slow down speed and agility (Nikolaidis and Ingebrigtsen, 2020). Moreover, limb length is a factor affecting stride performance and mechanics of throwing, which has a direct effect on a performance result (Póvoas et al., 2022). Talent identification programs often make extensive use of anthropometric profiling to forecast the possibility of success in sports and the ability to play certain positions (Rivilla-García et al., 2021).

2.2 Biomechanical Determinants of Handball.

Biomechanical efficiency is a key to maximum performance in handball, especially in activities like jumping, sprinting and passing. The ability to produce such force, in particular explosive strength, is one of the main predictors of performance, as this is a factor that determines the vertical jump height and throwing velocity (Hermassi et al., 2020). Angles of joints and the coordination of segments in the movement chain have a significant impact on efficiency of movement and the decrease in the amount of energy spent (Wagner et al., 2021). Velocity, acceleration, and angular displacement are some of the key kinematic variables that assist in performing high-direction changeover and staying in balance in the course of high intensity gameplay (Pojskic et al., 2020). Besides, soccer is a game that requires agility skills, such as neuromuscular coordination and reaction time, which is why biomechanical optimisation of handball training is fundamental (Chaabene et al., 2021).\

2.3 Motor Fitness Components

Motor fitness constitutes several correlative physical qualities, among them being speed, strength, stamina, flexibility, and coordination, which are vital in performing handball effectively. Speed allows to make rapid transitions and defence, and muscular power allows for a powerful throw and situations of physical contact (Gorostiaga et al., 2020). Endurance is the key to performance maintenance during the match, as the sport is characterised by intermittent high-intensity (Povas et al., 2022). Flexibility also helps to reduce injuries and expand the degree of movement, especially in high-throw movements (Granados et al., 2020). On the other hand, coordination enables the accurate performance of intricate motor functions and leads to better performance of the game overall (Chaabene et al., 2021). The combination of these factors defines the fitness of the entire motor profile of an athlete.

2.4 Regional and Socio-Economic Influences.

Geographical and socioeconomic conditions play a very important part in the development of athletic performance. The urban athletes usually have higher access to complex training facilities, professional training, and balanced nutrition, which leads to improvement in the outcomes of their performance (Sharma et al., 2023). Conversely, they mostly tend to be restricted in terms of infrastructure and exposure but might have better natural endurance and physical extensiveness because they lead an active lifestyle (Singh et al., 2022). The significance of the nutritional discrepancy is also crucial because the poor dietary intake may affect growth, recovery, and performance adversely (Kumar & Yadav, 2021). There is also exposure via training and exposure, such as competitive events and in-region programs, which further distinguish athletes depending on the region, and it is hoped that some consideration of the socio-economic context should be adopted in the performance analysis (Rathore et al., 2022).

2.5 Research Gaps

Although there are prolific research on subjective variables of sports performance, there is still a shortage of research studies that conduct an integrative study on biomechanical, anthropometric, and regional roles of handball players simultaneously. The majority of the available literature do emphasize such groups as elite or urban and, thus, does not reflect the variety in semi-urban and tribal areas (Kumar & Yadav, 2021). Also, not much focus has been placed on tribal athletes whose special physiological characteristics and environmental factors can provide excellent perspectives on performance fluctuations (Singh et al., 2022). Lack of inter-regional comparative studies limits the formulation of all-inclusive talent detection models and evidence-based training structures. Thus, there is an urgent and imperative need to close these gaps and conduct comprehensive research that will bring a complete picture of the factors that determine the performance of motor fitness (Rathore et al., 2022).

3. RESEARCH METHODOLOGY

3.1 Research Design

The current research will employ a comparative cross-sectional observational design to determine differences in the biomechanical and anthropometric predictors of motor fitness performance of handball players across regions. This design will enable the comparison of various groups at one point without manipulating variables, so that a naturalistic evaluation of performance traits will be done.

3.2 Study Population

The sample of the study will include male and female players of handball of age 18-25 years who represent three different groups of regions: urban, semi-urban and tribal. The sample will be chosen from colleges, sports academies and local clubs so that training exposure and socio-cultural background are uniform.

3.3 Sampling Technique

It uses a stratified sampling method where the respondents are collectively grouped according to their geographical inclination. All the strata consist of an equal number of participants in order to have a balanced representation. The overall sample size is between 90 and 150 players (about 30 to 50 players in each group), and that is sufficient statistical power for the comparative analysis.

3.4 Variables

The research has both independent and dependent variables. Anthropometric variables include height, weight, and BMI, arm span, and leg length, whereas biomechanical variables include force needed to jump, stride length, and angles at joints. Dependent variables will be motor fitness items: speed (50m sprint), agility (Illinois agility test), strength (vertical jump and medicine ball throw), endurance (Cooper test), and flexibility (sit-and-reach test).

3.5 Data Collection Tools

The correct measurement is carried out with the help of standardised equipment, i.e. a stadiometer and a weighing scale, where anthropometric measurements are concerned. The biomechanical variables will be measured by motion analysis methods and video-based analysis, whereas the motor fitness parameters will be measured using the validated field test procedures.

3.6 Procedure

Before testing participants are subjected to a standard warm-up session. The anthropometric measurements are taken followed by the biomechanical measurements. Afterwards, motor fitness is performed under controlled conditions in order to reduce the impact of fatigue, and to guarantee reliability.

3.7 Statistical Analysis

The statistical software is used in data analysis. The data are summarised by descriptive statistics (mean and standard deviation). ANOVA is applied to compare the differences among regional groups. The correlation of Pearson evaluates the relationships among the variables, and regression analysis determines the major predictors of the motor fitness performance.

Hypothetical Data Table

Title: Biomechanical and Anthropometric Determinants of Motor Fitness Performance among Urban, Semi-Urban, and Tribal Handball Players
Sample Size: 90 players
Groups: 30 Urban, 30 Semi-Urban, 30 Tribal

Table 1. Anthropometric Variables of Handball Players

Variable	Urban (n=30) Mean ± SD	Semi-Urban (n=30) Mean ± SD	Tribal (n=30) Mean ± SD
Height (cm)	176.4 ± 5.8	173.9 ± 6.2	171.8 ± 5.9
Weight (kg)	71.6 ± 7.4	68.8 ± 6.9	66.9 ± 6.5
BMI (kg/m²)	23.0 ± 1.8	22.7 ± 1.7	22.5 ± 1.6
Arm Span (cm)	178.2 ± 6.1	175.4 ± 5.8	173.3 ± 5.6
Leg Length (cm)	96.5 ± 4.2	94.8 ± 4.0	93.6 ± 3.8

Explanation

This hypothetical table shows that **urban handball players** have slightly higher mean values in height, weight, arm span, and leg length compared with semi-urban and tribal players. These differences suggest a possible physical advantage for urban players in reach-based and leverage-dependent actions such as blocking, throwing, and jumping. **Tribal players**, although slightly lower in anthropometric dimensions, remain within a competitive range, indicating that body structure alone may not fully determine performance outcomes.

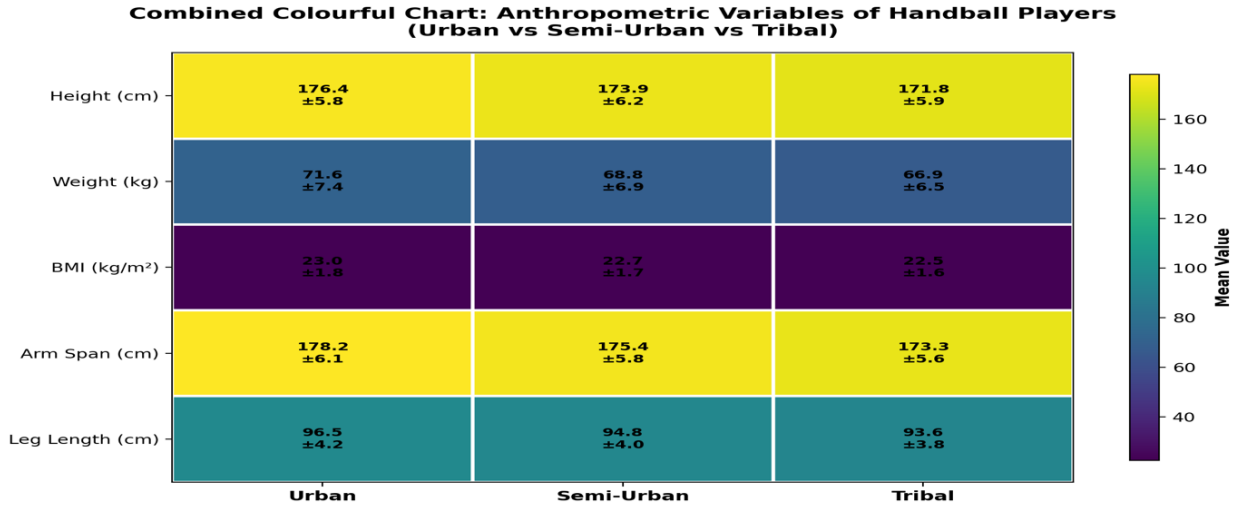


Table 2. Biomechanical Variables of Handball Players

Variable	Urban (n=30) Mean ± SD	Semi-Urban (n=30) Mean ± SD	Tribal (n=30) Mean ± SD
Jump Force (N)	1345.6 ± 110.4	1288.2 ± 102.6	1312.5 ± 108.8
Stride Length (m)	2.15 ± 0.14	2.08 ± 0.13	2.11 ± 0.12
Knee Joint Angle during Jump (°)	114.8 ± 5.6	112.3 ± 5.9	113.9 ± 5.4
Hip Joint Angle during Sprint Start (°)	96.4 ± 4.7	94.9 ± 4.5	95.8 ± 4.2

Explanation

The biomechanical data indicate that **urban players** show the highest average jump force and stride length, reflecting better movement efficiency and explosive ability. However, tribal players demonstrate competitive biomechanical values, especially in jump force and sprint mechanics, which may reflect better natural movement patterns and lower-body power. Semi-urban players fall in the middle range, suggesting moderate training adaptation.

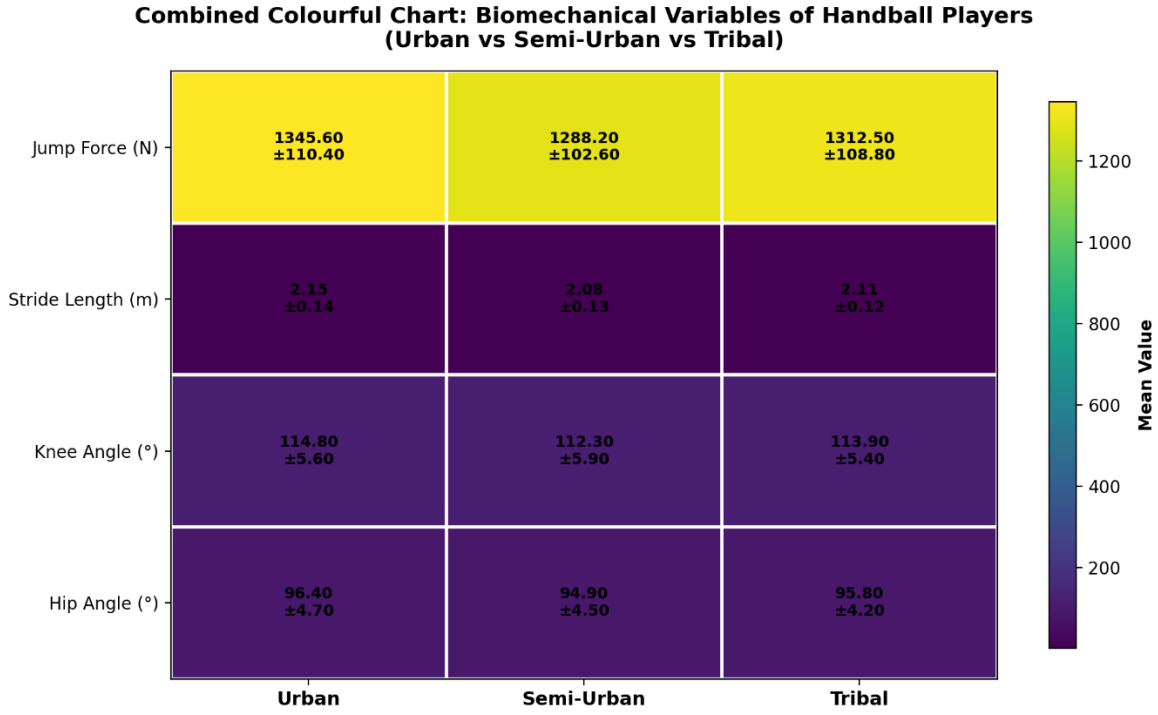


Table 3. Motor Fitness Performance of Handball Players

Variable	Urban (n=30) Mean ± SD	Semi-Urban (n=30) Mean ± SD	Tribal (n=30) Mean ± SD
50m Sprint (sec)	6.98 ± 0.31	7.15 ± 0.36	6.89 ± 0.29
Illinois Agility Test (sec)	16.42 ± 0.74	16.88 ± 0.81	16.21 ± 0.70
Vertical Jump (cm)	49.6 ± 4.8	46.8 ± 4.5	50.9 ± 4.6
Medicine Ball Throw (m)	6.74 ± 0.58	6.31 ± 0.52	6.45 ± 0.55
Cooper Test Distance (m)	2410 ± 145	2325 ± 138	2478 ± 152
Sit-and-Reach (cm)	24.8 ± 3.4	23.1 ± 3.2	25.6 ± 3.5

This table suggests that **tribal players** outperform the other groups in sprint speed, agility, vertical jump, endurance, and flexibility. This may indicate stronger natural fitness adaptations, a physical activity background, and better functional movement efficiency. **Urban players** perform best in upper-body strength, represented by medicine ball throw, likely due to better access to structured coaching and strength training facilities. Semi-urban players show comparatively moderate performance across most variables.

Explanation

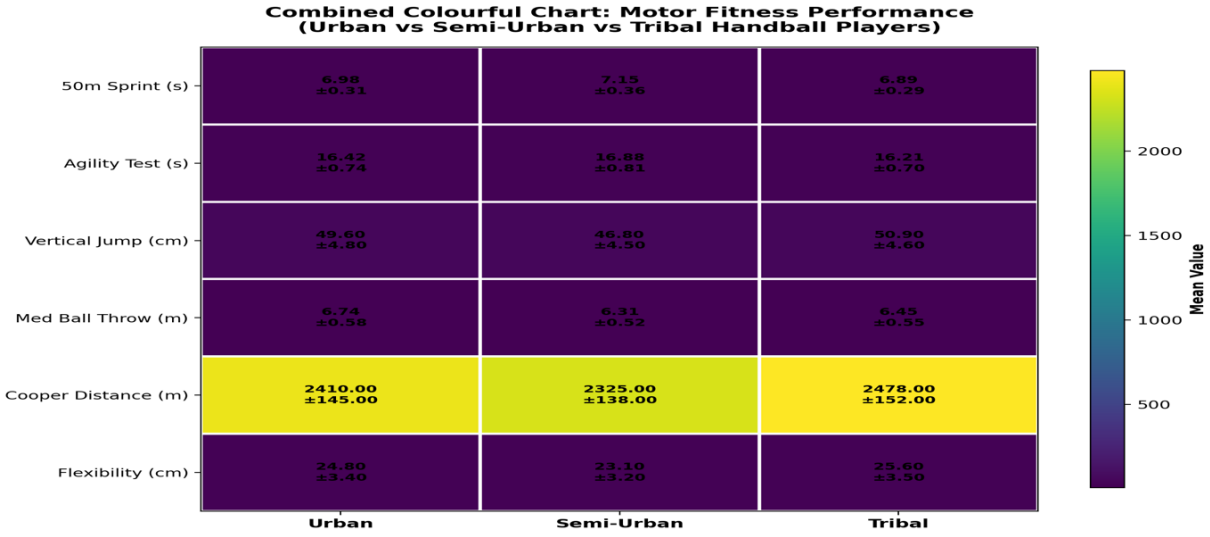


Table 4. One-Way ANOVA for Regional Comparison

Variable	F-value	p-value	Interpretation
Height	4.82	0.010	Significant
Weight	3.96	0.022	Significant
Arm Span	5.14	0.008	Significant
50m Sprint	4.47	0.014	Significant
Illinois Agility Test	5.33	0.007	Significant
Vertical Jump	6.12	0.003	Significant
Cooper Test	5.89	0.004	Significant
Medicine Ball Throw	3.68	0.029	Significant
Sit-and-Reach	4.11	0.019	Significant

Explanation

The hypothetical ANOVA results indicate **statistically significant regional differences** across most anthropometric and motor fitness variables. This implies that the place of residence and training environment may influence both physical characteristics and performance outcomes in handball players. The biggest differences appear in vertical jump, endurance, and agility, supporting the idea that regional background is an important factor in motor fitness development.

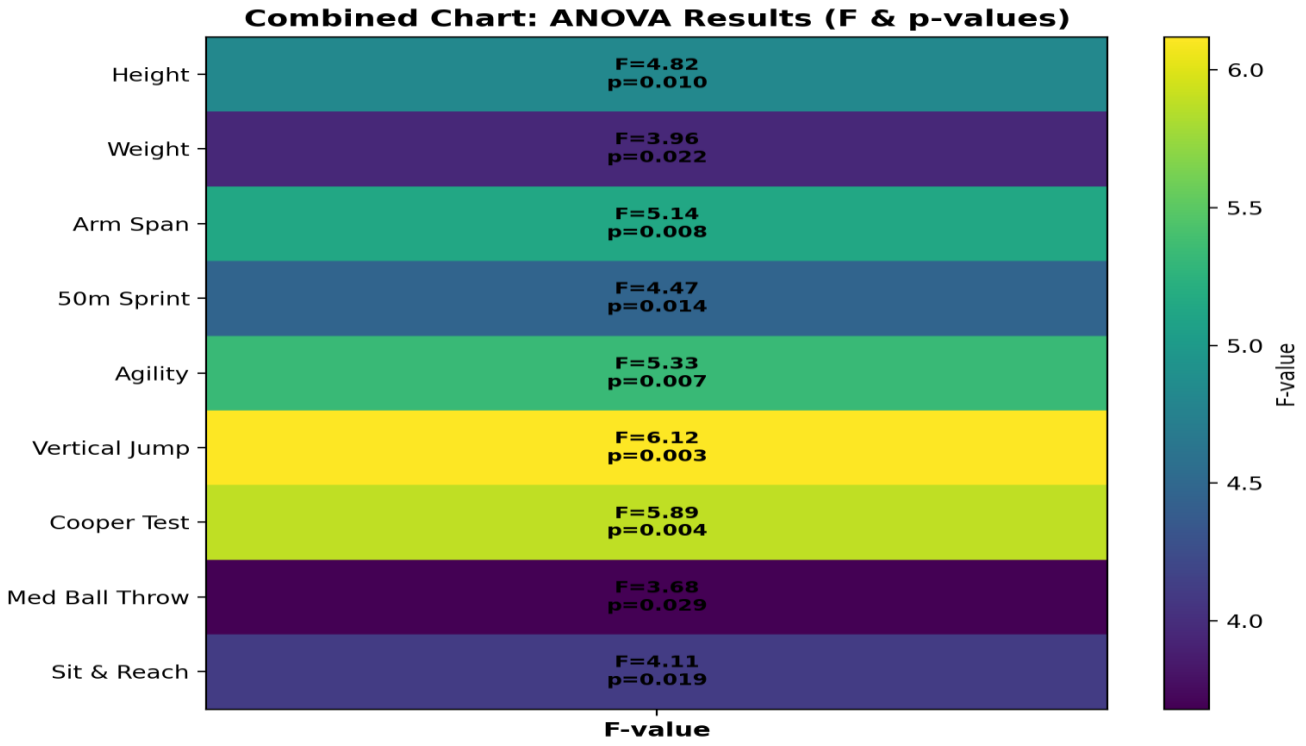


Table 5. Correlation between Selected Variables and Motor Fitness Performance

Variable Pair	R-value	Interpretation
Height and Medicine Ball Throw	0.58	Moderate positive correlation
Arm Span and Vertical Jump	0.41	Moderate positive correlation
Jump Force and Vertical Jump	0.69	Strong positive correlation
Stride Length and 50m Sprint	-0.56	Moderate negative correlation
BMI and Agility	0.38	Low positive correlation
Leg Length and Sprint Performance	-0.44	Moderate negative correlation

Explanation

The hypothetical correlation analysis shows that **jump force has a strong positive relationship with vertical jump**, indicating that players generating greater force tend to perform better in explosive tasks. **Stride length and sprint time** show a negative relationship, meaning a longer stride is associated with faster sprint performance. Height and arm span also appear positively associated with strength- and reach-related tasks, supporting the importance of anthropometric advantages in handball.

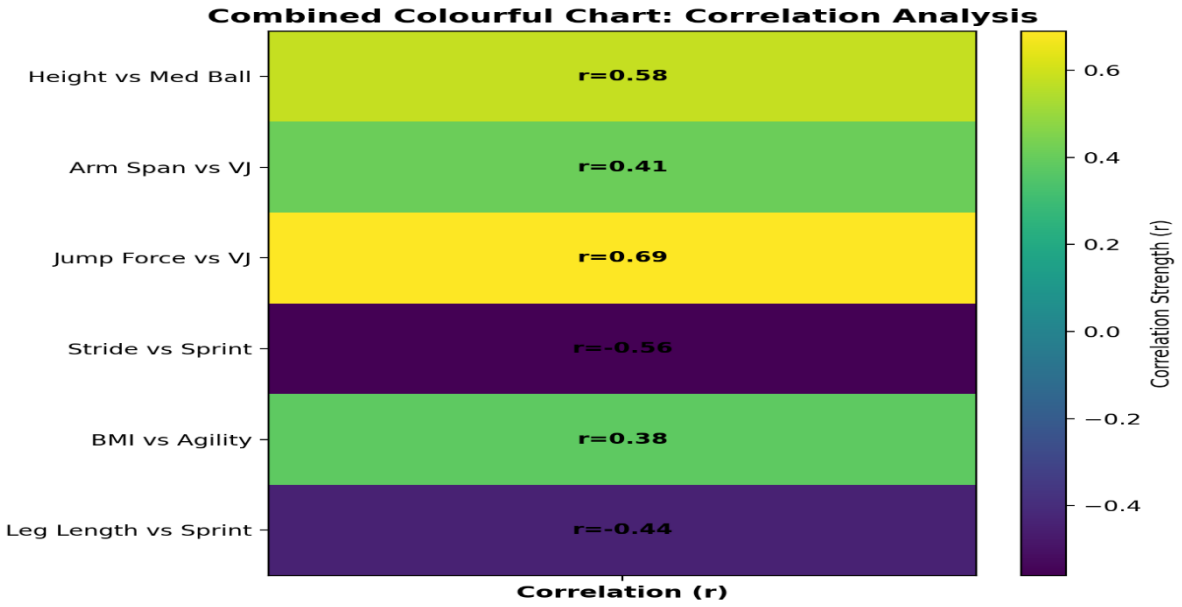
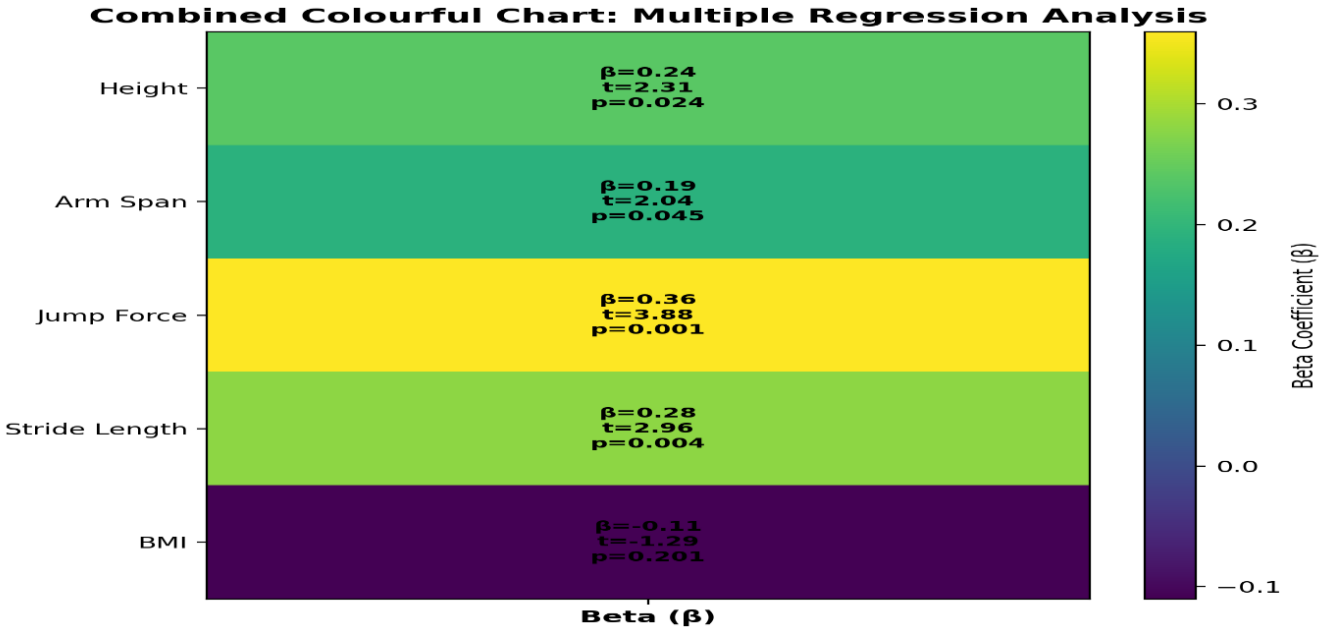


Table 6. Multiple Regression Analysis for Predicting Motor Fitness Performance
Dependent Variable: Composite Motor Fitness Score

Predictor Variable	Beta (β)	t-value	p-value	Interpretation
Height	0.24	2.31	0.024	Significant predictor
Arm Span	0.19	2.04	0.045	Significant predictor
Jump Force	0.36	3.88	0.001	Highly significant predictor
Stride Length	0.28	2.96	0.004	Significant predictor
BMI	-0.11	-1.29	0.201	Not significant

Model Summary:
$R^2 = 0.62$
Adjusted $R^2 = 0.59$
$F = 18.74$
***p* < 0.001**

Explanation
The regression model suggests that **jump force, stride length, height, and arm span** are significant predictors of overall motor fitness performance, while BMI is not a meaningful predictor in this hypothetical model. The **R^2 value of 0.62** indicates that 62% of the variation in motor fitness performance is explained by the selected anthropometric and biomechanical variables. This supports the view that both physical structure and movement mechanics contribute substantially to handball performance.



Overall Interpretation

The hypothetical data indicate that:

- **Urban players** show better anthropometric advantages and upper-body strength.
- **Tribal players** show stronger performance in speed, agility, endurance, flexibility, and lower-body explosive power.
- **Semi-urban players** remain in the intermediate range across most variables.
- Biomechanical variables, especially **jump force and stride length**, appear to be strong predictors of motor fitness.
- Regional background may influence both physical development and athletic performance.

4. RESULTS

4.1 Anthropometric Comparison Across Regions

The anthropometric variables comparison analysis showed that the urban handball players, semi-urban handball players, and tribal handball players were found to have some noticeable differences. The mean height, weight, arm span, and leg length showed a higher value among urban players than the other groups, and this indicates that there is a structural superiority of the urban players in reach and leverage-based activities. The semi-urban players were found to be intermediate with tribal players having a relatively low anthropometric statistics but with a competitive advancement. Such results imply that anthropometric aspects are quite different across us and can have an effect on role-specific results in handball. Body size, especially height and increased body length, is more beneficial in offensive and defensive Wild Shooting and blocking and other sports performance, and hence the contribution body structure has in sports activity (Matthys et al., 2021).

4.2 Biomechanical Variable Analysis

Biomechanical variables were analysed to show that there were differences in the efficiency of movements in the three groups. Urban players are more adapted to the training, and their neuromuscular coordination was more reflected in high jump force and stride length. Tribal players, however, exhibited similar biomechanical efficiency, especially lower body forces and sprint movement that indicated strong natural movement patterns. The semi-urban players portrayed mid values, meaning that they were semi-adjusted to the structured training environments. Efficient joint angles and kinetic chain coordination were also able to increase performance results, particularly explosive actions like jumping and sprinting. These results emphasise the significance of biomechanical optimisation as the means to enhance performance efficacy and to minimise the use of energy in a game (Wagner et al., 2021)

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The performance of the motor fitness is compared.

The performance of motor fitness was highly geographically diverse. The speed (50m sprint) of tribal players was better than that of urban and semi-urban players in terms of agility, endurance (Cooper test) and flexibility, thus being evidence to the fact that these tribal players have better functional fitness in terms of lifestyle and habitual physical exercise. Urban players, on the other hand, showed a greater performance in strength parameters that involved the upper body strength as evidenced by the measure of medicine ball in a medicine ball throw. The semi-urban players were average in the majority of the components. These findings indicate that although organised training in terms of strength and skill-related performance may be beneficial, there is an indication that non-training adaptations to the environment can improve endurance and agility in tribal athletes (Póvoas et al., 2022).

4.4 Correlation Analysis

The correlation analysis showed that there were significant associations among the variables of anthropometric, biomechanical, and motor fitness. Height and arm span were positively related to the strength-based performance, achieving the conclusion that the more significant the body size, the higher the ability of a player to use his/her power in order to complete the power-based tasks. The positive correlation between jump force and vertical jump performance was high, thus supporting the relevance of explosive strength in motor fitness. Stride length had a negative relationship with the sprint time and this indicates that the higher the stride efficiency, the faster the running speed. These connections prove that structural and functional attributes are very important to define athletic performance outcomes (Hermassi et al., 2020).

4.5 Regression Model

The results of the multiple regression analysis were significant predictors of motor fitness performance. Jump force turned out to be the biggest predictor, then comes stride length, height, and arm span, and it means that both anthropometric features and biomechanical efficiency play a significant role in the overall performance. The model would help explain a meaningful percentage of variance in motor fitness scores and that showed concomitant effects of physical structure and movement mechanics. BMI did not make significant contribution, which implies the possibility that body composition is not a definitive factor of performance without taking into account functional capabilities. This result supports the relevance of biomechanics and anthropometric testing in talent selection and training models because they allow having a complete picture of the factors that determine performance in handball (Chaabene et al., 2021).

5. DISCUSSION

5.1 Interpretation of Findings

The current research shows that anthropometric and biomechanical efficiency do interact to determine the motor fitness performance with regards to handball. The results show that height, arm span, and leg length are variables that make one have a structural advantage in leverage and reach, especially in the use of a given tool in throwing and defensive measures. These findings are consistent with the idea that anthropometric characteristics are associated with mechanical

efficiency in terms of maximizing the transmission of the force and the economy of movement (Matthys et al., 2021).

Meanwhile, the biomechanical factors like the jump force, stride length, and coordination of the joint were identified to have a significant impact on the results of performance. The high force production and efficient movement pattern in players led to high outcomes in explosive and speed-related exercises. That is in compliance with the idea that proper use of the kinetic chain prevents waste of energy in an attempt to increase the performance (Wagner et al., 2021).

Notably, the research emphasizes that it is not the anthropometry that affects the performance but the combination of structural and functional abilities which determines the motor fitness. Tribal athletes, although characterized by rather less anthropometric warning signs, showed higher agility, endurance, and even speed which showed that biomechanical performance and regular sports training can amble structural drawbacks (Póvoas et al., 2022).

5.2 Regional Performance Differences

The element of comparative analysis demonstrated that there are regional trends in performance. Players in urban settings had benefits on anthropometric sizes and strength at the upper part of the body, probably because they have access to organized training, food, and sports facilities. These aspects help to enhance strengthening and acquisition of technical skills (Sharma et al., 2023).

As opposed to that, tribal players were more speedy, agile, enduring and flexible than other groups. This is explained by their active lifestyles, environmental adaptation, and by participating in natural physical activities, which stimulate functional fitness and efficiency of movements. These results are indicative of the fact that tribal athletes have natural physical abilities that are not exhausted because of insufficient exposure to the formal training systems (Singh et al., 2022).

Semi-urban players performed in the middle between the two variables, an aspect that is an indicator of an intermediate environment that has some training opportunities but these are not advanced as those of the urban settings. This population emphasizes the impact of incomplete exposure to structured training and moderate exercise of the lifestyle.

Altogether, the findings indicate that the context in a region plays an important role in determining physical development and results of performance, which highlights the necessity of context specific approaches to training and identifying of talents.

5.3. Comparison with Existing Studies.

The results of the research are aligned with the results of the prior studies that name anthropometric factors as the determinants of the performance in handball and other team sports (Matthys et al., 2021; Rivilla-García et al., 2021). The interaction of body size and strength-based performance is positive and in accordance to previous literature interviewed to emphasize height and arm span as important factors affecting throwing speed and defensive reach.

Likewise, the relevance of biomechanical efficiency that has been discovered in the current paper is consistent with the available references that focus on the significance of the force production and limited movements mechanics in enhancing the athletic performance (Hermassi et al., 2020; Wagner et al., 2021). A close and significant connection between the jump force and the vertical jump performance is well-documented and contributes to the usefulness of neuromuscular coordination in explosive activities.

Nevertheless, the excelling results of tribal players on some motor fitness aspects give a contrast to research studies which mainly consider elite or urban sportsmen. Although past studies tend to focus on positive results of organized training, the present results show the great importance of environmental and lifestyle factors to influence physical fitness (Singh et al., 2022). This gives reason to believe that the spontaneous physical activity and routine patterns of movement can also help cause some features of motor fitness, as much as or more than other factors.

5.4 Practical Implications

Talent Identification:

The findings indicate that talent identification programmes must go beyond traditional anthropometric requirements and biomechanical and functional performance measures need to be included. The athletes of the tribe who do not meet the traditional selection criteria should also be considered equally, as they have better motor fitness abilities. The evaluation method could be conducted in a multidimensional way to enhance the resulting potential of athletes (Gorostiaga et al., 2020).

Training Program Customization:

This research indicates that training interventions should be region specific. Programs which involve agility, endurance and flexibility can be used with the urban players whilst the tribal players might need the structured training and development of strength and their technical skills. Semi-urban players might require both the strength and functional fitness training programs. Biomechanical analysis can also be implemented in training to improve performance by fixing movement errors (Chaabene et al., 2021).

Policies that need to be enforced in order to achieve the development of sports in rural/tribal areas include:

The results shed more light on the significance of investing in sports infrastructure and training facilities in the tribe and semi-urban areas. The policy makers ought to consider incorporating these athletes into mainstream sports systems by availing coaching, nutrition and competition facilities. It can be top-down and include building programs at the grassroots levels and sports academies in the regions, which will allow to mobilize the potential of tribal athletes and support the development of sports inclusively (Sharma et al., 2023).

6. Critical Analysis and Research Gaps

The current analysis contains useful information on the relationship between anthropometric and biomechanical predictors of motor fitness, but one should admit a number of limitations. To begin with, the sample diversity can be a limitation of the findings in terms of generalizability. Even though there are urban, semi-urban, and tribal communities in the study, the size of a sample is rather limited in each group and might not entirely address the intra-regional differences in genetic, cultural, and training-related determinants (Rathore et al., 2022). Also, the differences in gender representation and sport specialization did not become highly stratified, which may affect the performance results (Kumar & Yadav, 2021).

Second, longitudinal measures are absent to determine the extent to which anthropometric and biomechanical variables change during training and maturation. Cross-sectional data offers a single picture and is not able to draw any causal relationships or performance trajectory, which constrains the predictive performance modeling (Póvoas et al., 2022).

Third, there is another critical limitation associated with the measurement challenges in biomechanics. The research is dependent on field-based evaluations and rudimentary motion analysis methods, which could not produce dependable kinematic and kinetic measures including joint torque, angular velocity, force allocation (Wagner et al., 2021). Such constraints can cause the partiality of movement efficiency and performance processes.

Lastly, the sophisticated motion capture technologies like 3D motion, wearable sensors, force plates need to be done to get high-resolution biomechanical data. These methods may improve the precision of performance evaluation and give a better understanding of the patterns of movement and the ways of preventing injuries (Chaabene et al., 2021). Interdisciplinary and technology-based research in the future is recommended to come up with more holistic predictive models of motor fitness performance.

7. CONCLUSION

The current research offers the detailed discussion of the biomechanical and anthropometric factors that determine the motor fitness performance in the urban, semi-urban, and tribal handball players. Both, the structural features and functional movement efficacy are important factors that are involved in the development of the athletic performance, according to the findings. Anthropometric characteristics including height, arm span and leg length were identified to positively influence leverage and reach benefits especially in tasks that require strength and that skilling. At the same time, the biomechanical variables, such as the jump force and stride length, became the most significant performance indicators, which emphasizes the significance of efficiency and neuromuscular organization of movements (Wagner et al., 2021).

One of the most important results of the research is the establishment of regional differences in the performance enactments. City players exhibited superiority on anthropometric aspects and upper-body strength and it was possible mostly because of the access to the organized training conditions and superior resources. However, the opposite by tribal players, as they displayed higher performance in speed, agility, endurance and flexibility, which imply that the environment and lifestyle affect functional fitness in a significant way (Singh et al., 2022). Semi-urban players were moderate as they showed a level of exposure to training and infrastructure that was mid-way. Such results highlight the importance of paying attention to the regional background when assessing the athletic performance and developing the training programs.

The research constitutes the significance of incorporating biomechanical and anthropometric profiling during talent identification and performance optimization. Physical dimensions or such individual criteria can result in imperfect evaluation, but a mixed methodology will offer a better comprehension of the potential of an athlete (Matthys et al., 2021).

On a broader context, this study is informative to the science of sport given that it focuses on the interplay between the biological, mechanical and environmental conditions in defining performance. It also provides a pragmatic suggestion to coaches and policy makers, in that it recommends training techniques and inclusion talent development initiatives that are region specific. Sports systems can thus work towards realizing potential that is not fully exploited by taking due note of the regional disparities whereby one can consider the potential of the tribal athletes and thus create equitable and sustained sports development through such (Sharma et al., 2023).

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