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Somatic Characteristics and Growth Patterns of Tribal Adolescents in Tripura: A Cross-Sectional Study

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Abstract

Introduction: Despite growing evidence on adolescent growth and nutritional status in India, limited cross-sectional research has examined age- and sex-related variation in body size, body composition, skeletal dimensions, and somatotype within a single framework among tribal adolescents in Tripura. To address this gap, the present study examined the somatic characteristics and growth patterns of tribal adolescents in two selected Autonomous District Council areas of Tripura using a cross-sectional design. The present study investigates the somatic features and growth trends of tribal adolescents in Tripura, India, employing a cross-sectional design. Methods: A total of 503 tribal adolescents (264 boys and 239 girls) were selected through incidental sampling, with the intention of maintaining an even distribution across three age brackets: 11.6–13.5 years (Group 1), 13.6–15.5 years (Group 2), and 15.6–17.5 years (Group 3). Results: The findings reveal distinct developmental patterns that deviate from conventional growth models, with clear age- and sex-related differences in anthropometric variables. The findings showed clear age- and sex-related variation in growth and body composition. Boys demonstrated progressive increases in height, body weight, and lean mass across age groups, together with declining endomorphy and increasing ectomorphy, indicating a gradual shift toward a more mesomorphic-ectomorphic physique. Girls also showed age-related increases in body size, but they displayed higher fat percentage, increasing endomorphy, and a stronger endomorphic-mesomorph profile in later adolescence. Skeletal breadths and limb girths increased in both sexes, although boys showed larger limb girths while girls demonstrated notable increases in humerus and femur breadths. Conclusion: This research supports the importance of population-specific growth references and highlights the necessity of culturally informed approaches to sports development among indigenous groups.

Keywords: Anthropometry, Youth Adolescent, Morphological growth, Fat Percentage, Ectomorphic Traits.

Resumen

Introducción: A pesar de la creciente evidencia sobre el crecimiento adolescente y el estado nutricional en la India, existen escasos estudios transversales que hayan examinado, dentro de un mismo marco analítico, las variaciones relacionadas con la edad y el sexo en el tamaño corporal, la composición corporal, las dimensiones esqueléticas y el somatotipo entre adolescentes tribales de Tripura. Para abordar esta laguna, el presente estudio analizó las características somáticas y los patrones de crecimiento de adolescentes tribales en dos áreas seleccionadas del Consejo Autónomo de Distrito de Tripura mediante un diseño transversal. **Métodos:** Se seleccionó un total de 503 adolescentes tribales (264 varones y 239 mujeres) mediante muestreo incidental, con la intención de mantener una distribución equilibrada en tres grupos etarios: 11,6–13,5 años (Grupo 1), 13,6–15,5 años (Grupo 2) y 15,6–17,5 años (Grupo 3). **Resultados:** Los hallazgos revelaron patrones de desarrollo diferenciados que se apartan de los modelos convencionales de crecimiento, con claras variaciones en las variables antropométricas según la edad y el sexo. Los resultados mostraron diferencias evidentes relacionadas con la edad y el sexo en el crecimiento y la composición corporal. Los varones presentaron aumentos progresivos en la talla, el peso corporal y la masa magra a través de los distintos grupos de edad, junto con una disminución de la endomorfia y un incremento de la ectomorfia, lo que indica un desplazamiento gradual hacia un físico más mesomórfico-ectomórfico. Las mujeres también mostraron incrementos relacionados con la edad en el tamaño corporal; sin embargo, presentaron un mayor porcentaje de grasa, aumento de la endomorfia y un perfil endomórfico-mesomórfico más marcado en la adolescencia tardía. Los diámetros óseos y los perímetros de las extremidades aumentaron en ambos sexos, aunque los varones mostraron mayores perímetros de las extremidades, mientras que las mujeres evidenciaron incrementos notables en los diámetros biepicondilares del húmero y del fémur. **Conclusión:** Este estudio respalda la importancia de contar con referencias de crecimiento específicas para cada población y pone de relieve la necesidad de enfoques culturalmente contextualizados para el desarrollo deportivo entre los grupos indígenas.

Palabras Clave: Antropometría, Adolescentes Jóvenes, Crecimiento Morfológico, Porcentaje De Grasa, Rasgos Ectomórficos.

Introducción

Adolescent growth is shaped by a complex interaction of biological maturation, nutritional status, physical activity, and environmental conditions. During this period, changes in height, body weight, body composition, skeletal breadths, and overall physique do not occur in the same way across all populations. Anthropometric assessment has therefore remained central to understanding human growth, while somatotype analysis has provided an added framework for interpreting the relative contribution of fatness, muscularity, and linearity to physical development (Heath & Carter, 1967). In India, earlier studies have shown that adolescent growth is strongly influenced by sex, with girls generally maturing earlier and boys tending to sustain gains in stature and lean tissue for a longer duration (Rogol, 2004; Wells, 2007). Research has also shown that boys and girls differ in fat distribution and body composition during puberty, making adolescence an especially important stage for population-specific growth assessment (Johnston et al., 1991; Liu et al., 2011; Liu et al., 2021).

Within this broader field, tribal populations deserve particular attention because their growth patterns may reflect distinct ecological, cultural, and nutritional influences. Studies from Northeast India have already indicated that tribal groups differ in body size, nutritional status, and anthropometric characteristics from more generalized Indian populations (Deka, 2011; Khongsdier, 2001; Roy et al., 2010). Work conducted in Tripura has further shown variation in nutritional status, fat patterning, and somatic characteristics among tribal children and adolescents (Das et al., 2023; Saha et al., 2017; Uddin et al., 2015). Some evidence also suggests that mesomorphic tendencies may be relatively prominent in tribal youth, even outside organized sports settings, which raises interesting questions about local growth patterns and physique development (Sarkar & Sil, 2014). At the same time, broader reviews of tribal health in India continue to show that undernutrition, socioeconomic disadvantage, and restricted access to health resources remain important influences on physical development in these communities (Biswas, 2022; Das & Bose, 2015; Phukon & Dhar, 2024).

Despite these contributions, an important gap remains. Much of the available literature has focused on isolated indicators such as body mass index, nutritional status, selected skinfolds, or general anthropometric description, rather than examining age- and sex-related changes in body size, body composition, skeletal dimensions, and somatotype within a single framework (Uddin et al., 2015). In Tripura especially, there is still limited cross-sectional evidence describing how tribal boys and girls progress across adolescence in relation to lean mass, fat percentage, limb girths, skeletal breadths, and somatotype components together. This makes it difficult to determine whether the developmental profile of tribal adolescents follows the same pattern typically described in broader Indian samples or whether it reflects population-specific features linked to local ecology and lifestyle (Deka, 2011). The absence of such integrated evidence also limits the interpretation of growth using generalized reference standards, which may not fully capture the diversity of adolescent development in indigenous populations.

The present study was undertaken to address this gap by examining the somatic characteristics and growth patterns of tribal adolescents in Tripura through a cross-sectional design. The present study aimed to examine the somatic characteristics and growth patterns of tribal adolescents in two selected Autonomous District Council areas of Tripura, with particular reference to age- and sex-related variation in anthropometric traits, body composition, skeletal dimensions, and somatotype. By addressing these objectives, the study seeks to provide a more integrated understanding of physique development in a tribal adolescent population that remains underrepresented in Indian growth research.

Methodology

The research adopted a cross-sectional approach to evaluate physical attributes and developmental trends in tribal adolescents from Tripura. The methodology was designed to guarantee thorough data collection and analysis, following standardized protocols and addressing the distinct socio-cultural context of the study population.

Study Population and Sampling

The target population comprised tribal students aged 11.6 to 17.5 years from Anandapur and Khumulwng Autonomous District Councils (ADCs) in Tripura. These regions were selected due to their high concentration of tribal communities and logistical feasibility. A total of 503 participants (boys = 264 and girls = 239) were recruited via incidental sampling, with the aim of achieving balanced distribution across three age groups: 11.6–13.5 years (Group 1), 13.6–15.5 years (Group 2), and 15.6–17.5 years (Group 3). Participants were excluded if they were undergoing regular sports training, as this could confound natural growth patterns.

Anthropometric Measurements

All measurements followed the International Society for the Advancement of Kinanthopometry (ISAK) guidelines (Heath & Carter, 1967). Information was gathered by Anthropometrist certified by ISAK to reduce differences between observers. The instruments used and their measurement precision are presented in Table 1, and the following parameters were recorded:

1. ***Standing Height:*** Height was determined by a stadiometer (SECA) with 0.1 cm precision, while participants were barefoot and maintained an upright posture.
2. ***Body Mass:*** Measurements were taken with a calibrated weighing device (Beat Xp) accurate to 0.1 kg.
3. ***Skinfold Thickness:*** Measurements were conducted at five anatomical locations (triceps, biceps, subscapular, supra-iliac, mid-calf) with a Harpenden caliper (Baty International), where each site was measured three times and the mean value was calculated.
4. ***Limb Girths:*** Arm and calf circumferences were determined with an anthropometric tape (Cescorf), recorded to the nearest 0.1 cm.
5. ***Skeletal Breadths:*** The bi-epicondylar widths of the humerus and femur were measured with a sliding caliper (Cescorf).

Table 1. Anthropometric Measurement Protocol

Measurement	Equipment	Precision
Standing Height	Stadiometer (SECA)	0.1 cm
Body Mass	Weighing Scale (Beat Xp)	0.1 kg
Skinfold Thickness	Harpenden Caliper	0.1 mm
Limb Girths	Anthropometric Tape	0.1 cm
Skeletal Breadths	Sliding Caliper	0.1 cm

Somatotype Classification

The Heath-Carter approach was applied to categorize somatotypes according to endomorphic, mesomorphic, and ectomorphic dimensions (Carter & Heath, 1990). Endomorphy was calculated from skinfold measurements, mesomorphy from limb girths and skeletal breadths, and ectomorphy from the height-to-weight ratio. The following equations were applied:

$$\text{Endomorphy} = -0.7182 + 0.1451 \times (\text{sum of triceps, subscapular, and supra-iliac skinfolds}) - 0.00068 \times (\text{sum}^2) + 0.0000014 \times (\text{sum}^3) \quad (1)$$

$$\text{Mesomorphy} = 0.858 \times \text{humerus breadth} + 0.601 \times \text{femur breadth} + 0.188 \times \text{corrected arm girth} + 0.161 \times \text{corrected calf girth} - \text{height} \times 0.131 + 4.5 \quad (2)$$

$$\text{Ectomorphy} = \frac{\text{height}}{\sqrt[3]{\text{weight}}} \times 0.732 - 28.58 \quad (3)$$

Data Analysis

Descriptive statistics were computed for all variables and are presented as mean and standard deviation. Anthropometric data were summarized separately by sex and by age group to identify growth-related patterns in body size, body composition, skeletal breadths, limb girths, and somatotype components. Fat percentage was estimated from skinfold measurements according to standard anthropometric procedures consistent with ISAK-based assessment practice. Somatotype components were calculated using the Heath-Carter method, and the results were interpreted comparatively across age groups and between boys and girls.

Ethical Considerations

Ethical approval was obtained from the institutional review board, and informed consent was secured from participants and their guardians. Data confidentiality was preserved, and assessments were carried out in a secluded environment to honor cultural norms.

Results

This study identifies unique somatic and growth patterns in tribal adolescents from Tripura, with observed differences in anthropometric traits based on age and gender. The following subsections present detailed results on growth trends, fat distribution, somatotype classifications, and skeletal development.

Table 2 presents age- and gender-specific anthropometric measurements for tribal adolescents across three age groups: 11.6–13.5 years, 13.6–15.5 years, and 15.6–17.5 years. In boys, height increased steadily from 148.1 ± 6.2 cm in the youngest group to 157.3 ± 5.8 cm in the middle group and 164.7 ± 6.1 cm in the oldest group, showing a clear age-related growth pattern. Body weight in boys followed the same trend, rising from 40.4 ± 5.7 kg to 47.2 ± 6.3 kg and then to 53.9 ± 7.1 kg, while lean mass also increased progressively from 35.34 ± 4.21 kg to 40.15 ± 4.87 kg and 44.33 ± 5.12 kg.

Among girls, height increased from 146.8 ± 5.9 cm in the youngest age group to 153.4 ± 5.5 cm in the middle group, with only a slight further rise to 154.1 ± 5.7 cm in the oldest group. Body weight increased consistently from 38.7 ± 5.2 kg to 43.1 ± 5.9 kg and 47.2 ± 6.5 kg, and lean mass also rose from 31.72 ± 3.98 kg to 34.89 ± 4.35 kg and 37.25 ± 4.61 kg across age groups.

Table 2. Age- and Gender-Specific Anthropometric Measurements

	Parameter	**11.6–13.5 years (n=88)**	**13.6–15.5 years (n=62)**	**15.6–17.5 years (n= 114)**
Boys	Height (cm)	148.1 ± 6.2	157.3 ± 5.8	164.7 ± 6.1
	Weight (kg)	40.4 ± 5.7	47.2 ± 6.3	53.9 ± 7.1
	Lean Mass (kg)	35.34 ± 4.21	40.15 ± 4.87	44.33 ± 5.12
	Parameter	**11.6–13.5 years (n=99)**	**13.6–15.5 years (n=63)**	**15.6–17.5 years (n= 77)**
Girls	Height (cm)	146.8 ± 5.9	153.4 ± 5.5	154.1 ± 5.7
	Weight (kg)	38.7 ± 5.2	43.1 ± 5.9	47.2 ± 6.5
	Lean Mass (kg)	31.72 ± 3.98	34.89 ± 4.35	37.25 ± 4.61

Table 3 describes skinfold thickness and fat percentage by age and gender, allowing comparison of subcutaneous fat distribution across growth stages. In boys, triceps skinfold increased from 4.25 ± 1.12 mm to 4.87 ± 1.25 mm and then to 6.25 ± 1.48 mm, while biceps skinfold also increased steadily from 5.32 ± 1.08 mm to 6.29 ± 1.34 mm and 6.81 ± 1.42 mm. Supra-iliac skinfold in boys rose from 7.25 ± 1.55 mm to 8.78 ± 1.72 mm in the middle age group and then declined slightly to 8.11 ± 1.63 mm in the oldest group. In contrast, body fat percentage in boys decreased gradually from 17.25 ± 3.21% to 16.54 ± 3.05% and 15.89 ± 2.97% with increasing age.

In girls, triceps skinfold changed from 5.09 ± 1.24 mm in the youngest group to 4.31 ± 1.18 mm in the middle group and then increased sharply to 8.82 ± 1.87 mm in the oldest group. Biceps skinfold remained high in the first two age groups at 8.55 ± 1.67 mm and 8.48 ± 1.63 mm, but dropped to 3.14 ± 0.95 mm in the oldest group. Supra-iliac skinfold remained relatively stable in girls across all age groups, ranging from 9.02 ± 1.75 mm to 9.45 ± 1.82 mm.

Table 3. Skinfold Thickness (mm) and Fat Percentage by Age and Gender

	Measurement	11.6–13.5 years (n=88)	13.6–15.5 years (n=62)	15.6–17.5 years (n= 114)
Boys	Triceps	4.25 ± 1.12	4.87 ± 1.25	6.25 ± 1.48
	Biceps	5.32 ± 1.08	6.29 ± 1.34	6.81 ± 1.42
	Supra-iliac	7.25 ± 1.55	8.78 ± 1.72	8.11 ± 1.63
	Fat %	17.25 ± 3.21	16.54 ± 3.05	15.89 ± 2.97
	Measurement	**11.6–13.5 years (n=99)**	**13.6–15.5 years (n=63)**	**15.6–17.5 years (n= 77)**
Girls	Triceps	5.09 ± 1.24	4.31 ± 1.18	8.82 ± 1.87
	Biceps	8.55 ± 1.67	8.48 ± 1.63	3.14 ± 0.95
	Supra-iliac	9.12 ± 1.78	9.02 ± 1.75	9.45 ± 1.82
	Fat %	18.07 ± 3.45	19.32 ± 3.58	20.89 ± 3.77

Unlike boys, girls showed a progressive increase in fat percentage with age, from 18.07 ± 3.45% to 19.32 ± 3.58% and finally, 20.89 ± 3.77%. Taken together, the data show that boys experienced a decline in overall body fat percentage despite increases in some skinfold measures, whereas girls showed a general rise in fat percentage with age (Table 3).

Table 4. Skeletal and Limb Measurements by Age and Gender

	Measurement	11.6–13.5 years (n=88)	13.6–15.5 years (n=62)	15.6–17.5 years (n= 114)
Boys	Humerus breadth (cm)	5.72 ± 0.38	5.86 ± 0.40	5.98 ± 0.42
	Femur breadth (cm)	8.82 ± 0.53	9.01 ± 0.56	9.12 ± 0.61
	Arm girth (cm)	22.15 ± 1.85	23.15 ± 1.98	25.12 ± 2.11
	Calf girth (cm)	33.15 ± 2.45	34.12 ± 2.58	35.22 ± 2.67
	Measurement	**11.6–13.5 years (n=99)**	**13.6–15.5 years (n=63)**	**15.6–17.5 years (n= 77)**
Girls	Humerus breadth (cm)	5.65 ± 0.36	5.92 ± 0.41	6.12 ± 0.45
	Femur breadth (cm)	8.75 ± 0.51	9.05 ± 0.55	9.05 ± 0.58
	Arm girth (cm)	21.08 ± 1.72	22.35 ± 1.85	23.45 ± 1.98
	Calf girth (cm)	31.08 ± 2.32	31.85 ± 2.45	32.15 ± 2.41

Table 4 presents skeletal breadths and limb girths by age and gender, reflecting changes in frame size and muscular development during adolescence. In boys, humerus breadth increased from 5.72 ± 0.38 cm to 5.86 ± 0.40 cm and 5.98 ± 0.42 cm, while femur breadth rose from 8.82 ± 0.53 cm to 9.01 ± 0.56 cm and 9.12 ± 0.61 cm. Arm girth also increased consistently from 22.15 ± 1.85 cm in the youngest group to 23.15 ± 1.98 cm and 25.12 ± 2.11 cm in the oldest group, and calf girth rose from 33.15 ± 2.45 cm to 34.12 ± 2.58 cm and 35.22 ± 2.67 cm.

Among girls, humerus breadth increased from 5.65 ± 0.36 cm to 5.92 ± 0.41 cm and 6.12 ± 0.45 cm across age groups. Femur breadth rose from 8.75 ± 0.51 cm in the youngest group to 9.05 ± 0.55 cm in the middle group and remained at 9.05 ± 0.58 cm in the oldest group. Arm girth increased steadily from 21.08 ± 1.72 cm to 22.35 ± 1.85 cm and 23.45 ± 1.98 cm, while calf girth showed a smaller increase from 31.08 ± 2.32 cm to 31.85 ± 2.45 cm and 32.15 ± 2.41 cm. These findings show that both boys and girls demonstrated age-related increases in skeletal breadth and limb girth, although boys generally had larger arm and calf girths than girls at corresponding age groups.

Table 5. Somatotype Component Scores by Age and Gender

Group	Endomorphy	Mesomorphy	Ectomorphy
Boys (n = 264)			
11.6-13.5 years	3.2 ± 0.8	4.1 ± 1.0	2.8 ± 0.9
13.6-15.5 years	2.9 ± 0.7	4.2 ± 1.0	3.1 ± 0.9
15.6-17.5 years	2.5 ± 0.7	4.3 ± 1.1	3.5 ± 1.1
Girls (n = 239)			
11.6-13.5 years	3.8 ± 0.9	4.5 ± 1.1	2.1 ± 0.7
13.6-15.5 years	4.1 ± 1.0	4.6 ± 1.1	1.9 ± 0.6
15.6-17.5 years	4.5 ± 1.1	4.8 ± 1.2	1.9 ± 0.6

Table 5 summarizes somatotype component scores for boys and girls across the three age groups, using endomorphy, mesomorphy, and ectomorphy values. In boys, endomorphy decreased from 3.2 ± 0.8 in the youngest group to 2.9 ± 0.7 in the middle group and 2.5 ± 0.7 in the oldest group. Mesomorphy in boys increased slightly from 4.1 ± 1.0 to 4.2 ± 1.0 and then to 4.3 ± 1.1, while ectomorphy increased more clearly from 2.8 ± 0.9 to 3.1 ± 0.9 and 3.5 ± 1.1. This pattern shows that boys became relatively less endomorphic and more linear with advancing age, while maintaining moderate mesomorphic development.

In girls, endomorphy increased from 3.8 ± 0.9 in the youngest group to 4.1 ± 1.0 and 4.5 ± 1.1 in the older groups. Mesomorphy also increased slightly from 4.5 ± 1.1 to 4.6 ± 1.1 and 4.8 ± 1.2, whereas ectomorphy declined from 2.1 ± 0.7 to 1.9 ± 0.6 and remained at 1.9 ± 0.6 in the oldest group. Thus, girls showed a progressive shift toward greater endomorphic and mesomorphic characteristics with age, accompanied by lower ectomorphic tendency. In comparison with boys, girls had higher endomorphy and mesomorphy but lower ectomorphy across all age groups, reflecting a clear sex difference in somatotype pattern during adolescence.

Discussion

The primary aim of the present study was to examine the somatic characteristics and growth patterns of tribal adolescents in Tripura by assessing age- and sex-related variation in anthropometric characteristics, body composition, skeletal dimensions, and somatotype components. The findings showed that both boys and girls experienced age-related increases in body size and skeletal measures, but the pattern of development differed clearly by sex. Boys demonstrated progressive gains in height, body weight, lean mass, and ectomorphic-mesomorphic tendency across age groups, whereas girls showed relatively higher fat percentage, increasing endomorphy, and a stronger endomorphic-mesomorph profile in later adolescence. Taken together, these results suggest that tribal adolescents in Tripura display distinct developmental patterns that may not be fully represented by generalized growth standards.

The present study suggests that adolescence among tribal adolescents of Tripura is not merely a phase of steady physical enlargement, but a period of clear biological differentiation during which boys and girls begin to follow distinct developmental pathways. Taken together, the changes observed in height, body weight, lean mass, fat percentage, skeletal breadths, limb girths, and somatotype indicate that adolescence in this population involves a broader reorganization of body structure rather than a simple increase in size alone. This point is particularly important in tribal populations, where developmental patterns may not fully correspond to generalized Indian or urban-based growth standards.

The age-related rise in height, weight, and lean mass seen in Table 2 reflects the expected progression of adolescent growth, yet the tempo of change differed clearly between boys and girls. Boys showed a more sustained increase across all age groups, especially in stature and lean mass, whereas girls appeared to progress more rapidly in the earlier age range and then level off somewhat in the oldest category. This pattern is consistent with the established view that girls generally attain peak height velocity earlier than boys, while boys continue linear growth and lean tissue accretion for a longer duration (Rogol, 2004; Rao et al., 2000; Wells, 2007). In this sense, the present results do not challenge the classical model of sex-specific adolescent growth; rather, they reinforce it within a tribal population of Northeast India. At the same time, studies from tribal communities in the region have documented lower absolute growth values when compared with more advantaged populations, often in relation to nutritional and socioeconomic constraints (Saha et al., 2017; Uddin et al., 2015). That perspective helps explain why the present sample shows a normal developmental sequence, even though the absolute values for height and body mass remain comparatively moderate.

The findings on skinfold thickness and fat percentage in Table 3 add an important layer to this interpretation. Among boys, triceps and biceps skinfolds increased with age, but overall fat percentage declined slightly, suggesting that lean tissue accumulated more rapidly than fat mass. In other words, some peripheral fat deposition persisted, yet muscular development became proportionally more dominant as adolescence progressed. Similar trends have been described in male adolescents by Johnston et al. (1991) and Rodríguez et al. (2004), who noted that increasing muscularity is often accompanied by reduced relative fatness during this stage of growth. In girls, however, the pattern was quite different. Fat percentage rose steadily across age groups, and the increase in triceps skinfold in the oldest group suggests a stronger tendency toward fat deposition during maturation. Wells (2007) identified this as one of the clearest biological distinctions of female puberty, while Liu et al. (2011) also reported that girls often display greater central and peripheral fat accumulation than boys in Asian populations.

One feature that deserves careful interpretation is the sharp reduction in biceps skinfold among older girls. On its own, this value appears inconsistent with the broader pattern of rising fat percentage and increasing endomorphy. However, isolated fluctuations at a single skinfold site are not uncommon in field-based anthropometric studies, especially during puberty when fat redistribution may occur unevenly across regions of the body. Chatterjee et al. (2006) reported similar site-specific inconsistencies in adolescent skinfold data, suggesting that such variation may reflect measurement sensitivity or regional fat redistribution rather than a genuine decline in overall adiposity (Chatterjee et al., 2006). Viewed in that context, the broader trend of increasing fatness in girls remains the more meaningful biological finding.

The skeletal and limb measurements shown in Table 4 further clarify how these developmental differences were expressed structurally. Boys maintained larger arm and calf girths across age groups, which supports the view that male adolescence in this sample was characterized by greater muscular expansion of the limbs. Girls, by contrast, showed notable increases in humerus and femur breadths, indicating that skeletal maturation remained an important and active part of female development. This is a significant observation, because discussion of female adolescence often focuses mainly on fat gain, whereas the present findings show that skeletal development was equally prominent. Seeman (2001) emphasized that adolescent bone growth is strongly shaped by sexual dimorphism, with girls reaching skeletal maturity earlier while boys continue to increase bone strength through muscle-related loading (Seeman, 2001). Greene and Naughton (2006) further argued that habitual physical activity and mechanical loading contribute substantially to skeletal adaptation. In the case of tribal adolescents, whose daily lives may involve more walking, outdoor activity, and uneven terrain, such ecological influences may help explain the degree of skeletal robustness observed here (Greene & Naughton, 2006).

These separate trends are brought together most clearly in the somatotype findings presented in Table 5. Boys showed declining endomorphy along with increasing mesomorphy and ectomorphy, pointing to a gradual shift toward a more mesomorphic-ectomorphic physique with age. Girls followed the opposite direction, with rising endomorphy and mesomorphy and consistently low ectomorphy, indicating a stronger endomorphic-mesomorph profile in later adolescence. Put simply, boys became relatively leaner and more linear while still retaining muscularity, whereas girls became more robust and comparatively fatter as they matured. Carter and Heath (1990) described adolescence as the period during which sex differences in somatotype become especially pronounced, and the present findings strongly reflect that principle. Norton et al. (1996) likewise observed that physically active boys often move toward mesomorphic dominance, while girls more commonly show a stronger endomorphic component during maturation. Support from the regional literature is also evident, as Sarkar and Sil (2014) reported mesomorphic dominance among tribal school boys in Tripura even in non-athletic groups. This suggests that the present results are not isolated observations, but may reflect a broader somatic tendency within tribal youth of the region (Roy Sarkar & Sil, 2014).

Even so, the literature does not point to a single uniform tribal pattern. Some studies have reported stronger endomorphic dominance among boys living in nutritionally vulnerable settings, often in association with lower activity levels or poorer dietary conditions (Das & Bose, 2015). Against that background, the relatively favorable mesomorphic progression seen in the present sample may reflect better habitual movement, functional adaptation, or community-specific lifestyle conditions rather than a generalized tribal profile. This makes the findings more nuanced and highlights the importance of interpreting tribal growth within its immediate social and environmental setting rather than through broad ethnic assumptions alone.

One of the most important implications of this study is therefore methodological as well as biological: tribal adolescents should not be understood only through generalized growth standards developed from urban or non-tribal populations. Previous studies from Tripura have already shown that tribal communities differ in nutritional status, fat distribution, and anthropometric characteristics (Deka, 2011; Sarkar & Sil, 2014). The present findings extend that evidence by showing that these differences are visible across the full developmental profile, including lean mass, skeletal breadth, and somatotype. This supports the argument of Roseman and Auerbach (2015) that human growth and body form are best understood within ecological and population-specific contexts rather than against a single universal norm.

The applied significance of these results is also considerable. From a sports science perspective, the increasing mesomorphic tendency and lean mass among boys may indicate improving potential for activities that depend on strength, speed, and power, while girls appear to follow a different but equally meaningful pathway characterized by skeletal robustness and sustained mesomorphic development. Although physique alone cannot determine performance, anthropometric structure remains an important component of movement efficiency, sport suitability, and athlete profiling (Satilmiş et al., 2023). A similar point may be made for public health. The steady rise in fat percentage among girls and the changing fat distribution patterns in both sexes suggest that adolescence is a particularly sensitive period for nutritional monitoring in tribal communities. This is especially relevant in populations where undernutrition, dietary transition, and emerging body-composition risks may coexist (Biswas, 2022). In that respect, the present findings indicate that changes in adolescent body composition may have longer-term implications for physical fitness, metabolic health, and functional capacity.

Several limitations should be considered when interpreting these findings. First, the cross-sectional design compares age groups at a single time point and cannot track individual growth across adolescence. Thus, the age-related patterns in Tables 2–5 reflect group-level trends rather than changes within the same adolescents. Second, the study includes a limited set of variables. While anthropometric and somatotype data describe physical development, the lack of information on pubertal status, diet, physical activity, and hormones restricts explanations of the mechanisms behind sex differences. This is crucial in adolescence, when growth, fat distribution, and body build are shaped by both biological maturation and environmental factors. Third, population coverage is limited. Tribal adolescents in Tripura are not homogeneous, and results from a restricted sample may not represent all tribal communities in the state. The findings should therefore be seen as characterizing the studied group rather than all tribal adolescents in the region. Nonetheless, the consistent patterns across height, lean mass, skinfolds, skeletal breadths, limb girths, and somatotype give the study strong internal coherence and provide a useful contribution to the scarce literature on adolescent growth and physique in tribal populations of Northeast India.

Conclusion

This study examined the somatic characteristics and growth patterns of tribal adolescents in Tripura and showed clear age- and sex-related differences in body size, body composition, skeletal development, and somatotype. Boys displayed continued gains in height, body weight, lean mass, and ectomorphic-mesomorphic tendency across age groups, whereas girls showed increasing fat percentage, continued skeletal breadth development, and a stronger endomorphic-mesomorph profile in later adolescence. These findings suggest that adolescent growth in tribal populations may not always be fully represented by generalized reference standards derived from non-tribal or urban populations. The study therefore contributes useful baseline evidence for understanding growth diversity among tribal youth in Northeast India. More broadly, it highlights the value of population-specific anthropometric research in improving the interpretation of adolescent physical development within distinct ecological and social contexts.

References

Biswas, S. (2022). A Study on Indigenous Food Consumption and Nutritional Outcomes of Tribal Population of Tripura. *Indian Agricultural Research Institute*. https://krishikosh.egranth.ac.in/items/fe45d8d0-6142-472a-8094-833919fe00bb

Chatterjee, S., Chatterjee, P., Bandyopadhyay, A. (2006). Skinfold thickness, body fat percentage and body mass index in obese and non-obese Indian boys. *Asia Pacific Journal of Clinical Nutrition*, 15(2), 231–235.

Das, P., Ghosh, K., Bose, A., Chatterjee, D., Bandyopadhyay, A.R. (2023). The role of anthropometric variables in assessment of obesity among Tripuri women of North-East India. *Papers on Anthropology*, 32(2), 59–67. https://doi.org/10.12697/poa.2023.32.2.04

Das, S., Bose, K. (2015). Adult tribal malnutrition in India: An anthropometric and socio-demographic review. *Anthropological Review*, 78(1), 47–65. https://doi.org/10.1515/anre-2015-0004

Deka, S. (2011). Health and Nutritional Status of the Indian Tribes of Tripura and Effects on Education. *Inquiries Journal*, 3(03). http://www.inquiriesjournal.com/articles/407/health-and-nutritional-status-of-the-indian-tribes-of-tripura-and-effects-on-education

Greene, D.A., Naughton, G.A. (2006). Adaptive Skeletal Responses to Mechanical Loading during Adolescence. *Sports Medicine*, 36(9), 723–732. https://doi.org/10.2165/00007256-200636090-00001

Heath, B.H., Carter, J.E. (1967). A modified somatotype method. *American Journal of Physical Anthropology*, 27(1), 57–74. https://doi.org/10.1002/ajpa.1330270108

Johnston, F.E., Sanjeev, Jit, I., Indech, G.D. (1991). Fatness and fat pattering in 12–17-year-old youth from the Chandigarh zone of Northwest India. *American Journal of Human Biology*, 3(6), 587–597. https://doi.org/10.1002/ajhb.1310030608

Khongsdier, R. (2001). Body mass index of adult males in 12 populations of Northeast India. *Annals of Human Biology*, 28(4), 374–383. https://doi.org/10.1080/03014460010004610

Liu, A., Byrne, N.M., Kagawa, M., Ma, G., Kijboonchoo, K., Nasreddine, L., Koon Poh, B., Ismail, M.N., Hills, A.P. (2011). Ethnic differences in body fat distribution among Asian pre-pubertal children: A cross-sectional multicenter study. *BMC Public Health*, 11(1), 500. https://doi.org/10.1186/1471-2458-11-500

Liu, C., Rahman, M.N.B.A., Yu, X., Yuan, L. (2021). A Visualized Analysis of the Research Literature on Early Childhood Family Education in China. *Open Journal of Social Sciences*, 09(11), 347-362. https://doi.org/10.4236/jss.2021.911025

Phukon, A.J., Dhar, K. (2024). A Comparison of Vertical Jump Performance between Mesomorphic and Ectomorphic Dominant Somatotypes. *International Journal of Kinanthropometry*, 4(1), 1-8. https://doi.org/10.34256/ijk2411

Rao, S., Joshi, S., Kanade, A. (2000). Growth in some physical dimensions in relation to adolescent growth spurt among rural Indian children. *Annals of Human Biology*, 27(2), 127–138. https://doi.org/10.1080/030144600282244

Rogol, A. (2004). Gender and hormonal regulation of growth. Journal of Pediatric Endocrinology & Metabolism. *Journal of Pediatric Endocrinology & Metabolism*, 17(4), 1259–1265.

Roy Sarkar, S., Sil, S. (2014). Somatotype of non-athlete tribal school boys of West Tripura District, Tripura. *Biolife*, 2, 1365–1370.

Roy, T.C., Springer, B.A., McNulty, V., Butler, N. L. (2010). Physical Fitness. *Military Medicine*, 175(8S), 14–20. https://doi.org/10.7205/MILMED-D-10-00058

Saha, S., Roy, S., Sil, S.K. (2017). Physical Growth and Nutritional Status of Chakma Tribal Children of Tripura. *Studies of Tribes and Tribals*, 15(1), 18–22. https://doi.org/10.31901/24566799.2017/15.01.03

Satilmiş, N., Söyler, M., Kilinçarslan, G. (2023). Comparison of Anthropometric Characteristics and Biomotor Ability Variables of Athletes in Different Combat Sports. *The Online Journal of Recreation and Sports*, 12(4), 829–837. https://doi.org/10.22282/tojras.1352653

Seeman, E. (2001). Sexual Dimorphism in Skeletal Size, Density, and Strength. *The Journal of Clinical Endocrinology & Metabolism*, 86(10), 4576–4584. https://doi.org/10.1210/jcem.86.10.7960

Uddin, M.J., Nag, S.k., Sil, S.k. (2015). Anthropometric Assessment of Nutritional Status of Adolescents in Rural School of Unokoti District of Tripura, North-East India. *Anthropologist,* 19(1), 277-284.

Wells, J.C.K. (2007). Sexual dimorphism of body composition. *Best Practice & Research Clinical Endocrinology & Metabolism*, 21(3), 415–430. https://doi.org/10.1016/j.beem.2007.04.007

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Conflicts of Interest

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Informed Consent Statement

All the athletes included in the study provided written informed consent.

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