Inter-District Variation in Anthropometric and Body Composition Characteristics of Adolescent Male Basketball Players from Uttar Pradesh, India: A Multivariate, Age-Adjusted Cross-Sectional Analysis

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Abstract

Stature, limb length, and lower-limb muscularity are recognised determinants of basketball performance and figure prominently in talent identification, yet comparative, multivariate, age-adjusted data for Indian adolescent male players are scarce. To profile and compare selected anthropometric and body-composition characteristics among inter-district adolescent male basketball players from seven district squads in Uttar Pradesh, India, using a multivariate framework while statistically adjusting for chronological age. Eighty male basketball players (mean age 16.64 ± 1.32 years) representing the BHU, BLW, Agra, Pilibhit, Gorakhpur, Gautam Buddh Nagar (GBN), and Varanasi squads were assessed for standing height, leg length, arm length, thigh and calf girths, and seven skinfolds. The sum of skinfolds (ΣSF) and relative body fat (Slaughter youth equation) were derived. After verifying normality (Shapiro–Wilk) and homogeneity of variance (Levene's test), a one-way MANOVA tested the overall district effect, followed by univariate ANOVAs with eta-squared and Tukey HSD; a one-way ANCOVA with age as a covariate confirmed robustness. Significance was set at $p < 0.05$. MANOVA revealed a significant overall district effect (Wilks' $\Lambda = 0.004$, $F_{42,318} = 17.61$, $p < 0.001$; multivariate $\eta^2 = 0.61$). Univariate tests showed significant differences for height ($p = 0.004$, $\eta^2 = 0.22$), leg length ($p < 0.001$, $\eta^2 = 0.31$), thigh girth ($p < 0.001$, $\eta^2 = 0.31$), calf girth ($p = 0.003$, $\eta^2 = 0.23$), and ΣSF ($p < 0.001$, $\eta^2 = 0.28$), but not arm length or estimated body fat. All five effects persisted after age adjustment (ANCOVA, all $p \leq 0.003$). GBN players were the tallest and longest-legged, BHU players carried the greatest thigh girth, and Pilibhit players showed the highest ΣSF. Adolescent male basketball players across the sampled districts share a homogeneous relative-adiposity profile but diverge robustly in linear dimensions and lower-limb girths, independent of age. The findings provide multivariate, age-adjusted baseline reference data to inform region-sensitive talent identification and conditioning.

Keywords: Basketball; Anthropometry; Body Composition; Skinfolds; Adolescent athletes; MANOVA; ANCOVA; Talent Identification

Introduction

Basketball asks a great deal of the body. Play unfolds as short, repeated bursts—sprinting, jumping, contesting at the rim—stitched together by brief moments of recovery, and how well a player meets those demands depends heavily on physique. Ziv and Lidor (2009) drew this point out in their wide-ranging review, and more recent work by Han, Gómez-Ruano, Lorenzo Calvo, and Lorenzo Calvo (2023) and by Vadillo-Ortega and Navarro (2025) has reinforced it: stature, limb length, and lower-limb muscularity keep surfacing as the attributes that separate stronger players from weaker ones and that nudge athletes toward particular roles. In a growing adolescent, none of this is fixed. As Malina, Bouchard, and Bar-Or (2004) explained, such characteristics emerge from genetics, nutrition, the timing of maturation, and years of training acting together—forces that differ sharply from one region to the next, a theme Čaušević et al. (2026) returned to in their study of maturity status in youth basketball.

Of the morphological traits that matter, the linear ones come first. Height and long limbs lift the points at which a player releases, blocks, and rebounds, and the meta-analysis by Han et al. (2023) confirmed that height and arm-span reliably tell higher- from lower-level players apart—an observation Drinkwater, Pyne, and McKenna (2008) had already built into their guidance on testing, and one that Ljubojevic et al. (2023) saw again in junior Euroleague squads. Leg length deserves particular attention, since its proportion to stature shapes both stride and the mechanics of the jump that defines so much of the game. Thigh and calf girths, meanwhile, give the field practitioner a quick read on lower-limb muscularity—the very tissue that drives jumping and sudden changes of direction—as Reilly, Bangsbo, and Franks (2000) noted for team sports generally and as Lukonaitiene et al. (2022) and Ramos, Volossovitch, Ferreira, Fragoso, and Massuca (2021) have shown in basketball specifically.

Body composition rounds out the picture by weighing lean tissue against fat. Extra fat is dead weight in a sport built on jumping and quick feet, whereas a leaner build helps with agility and repeated efforts; Nikolaidis et al. (2015)

and Toselli et al. (2020) both made this case in young players. Laboratory methods are rarely an option at the school or district level, so skinfolds remain the practical choice. Bonilla et al. (2022) showed that even the raw sum of skinfolds tracks adiposity well, while prediction equations use selected sites to estimate fat; the youth-specific formula of Slaughter et al. (1988) is popular precisely because it sidesteps the error that adult equations introduce in growing bodies. Stewart, Marfell-Jones, Olds, and de Ridder (2011) set out the ISAK standards that keep such measurements comparable across studies. A note of caution is in order, though: Jagim et al. (2023) and Devrim-Lanpir et al. (2021) have both reminded the field that every skinfold equation carries error in adolescent athletes, so a raw skinfold sum and an equation-derived percentage are best read side by side rather than treated as interchangeable.

There is a second wrinkle that adolescent studies too often skate past—maturation. Chronological age stands in for biological maturity during these years, so two players who differ in age may differ in height and muscle for reasons that have nothing to do with where they come from. Čaušević et al. (2026), Arede, Cumming, Johnson, and Leite (2021), and Mancha-Triguero, García-Rubio, Calleja-González, and Ibáñez (2021) have each documented how strongly maturity colours youth morphology and performance. Compare groups without accounting for age, and you risk crediting to region what really belongs to development—a trap that analysis of covariance is designed to avoid. A related concern arises when several correlated measures are examined at once: running a separate ANOVA for each inflates the chance of a false positive, which is why Tabachnick and Fidell (2019) recommend a multivariate test first.

For all this international groundwork, region-specific evidence on Indian adolescent players is thin, and studies that are at once comparative across districts, multivariate, and adjusted for age are thinner still. India is hardly uniform—diet, growth conditions, and training facilities vary widely—so it is reasonable to ask whether squads drawn from different districts of one large state look physically different. That question has roots in earlier Indian work: Sodhi (1980) profiled top Indian basketball players decades ago, and Bandyopadhyay (2007), Koley and Singh (2009), and Rhetso (2023) have since shown that physique and body composition vary across sports and regions within the country. To our knowledge, this is the first study to bring a multivariate and explicitly age-adjusted lens to inter-district anthropometric variation in Indian adolescent male basketball players, and its contribution is therefore methodological as much as descriptive: it supplies age-controlled regional reference values where the existing Indian literature has largely offered single-group, unadjusted profiles. The present study took up the question for adolescent male basketball players from seven district squads in Uttar Pradesh, with three aims: to describe each squad's means, dispersion, and 95% confidence intervals; to test for an overall multivariate district effect and, where it held, to pin down univariate differences with effect sizes and Tukey HSD; and to check, through ANCOVA with age as covariate, whether any difference outlasts adjustment for chronological age.

Materials And Methods

Research Design

A descriptive, comparative, cross-sectional design with a quantitative approach was adopted. The independent variable was district/squad of representation (seven groups); the dependent variables were the selected anthropometric and body-composition measures. Chronological age served as a covariate in the confirmatory analysis.

Participants and Sample-Size Considerations

Eighty male basketball players (N = 80) who had qualified for inter-district competition formed the sample: BHU (n = 12), BLW (n = 12), Agra (n = 12), Pilibhit (n = 9), Gorakhpur (n = 11), GBN (n = 12) and Varanasi (n = 12), with a mean age of 16.64 ± 1.32 years (range 15–19). Players were recruited by purposive sampling on the basis of current representation in district competition. With seven groups and N = 80 ($\alpha = 0.05$), the design provided adequate sensitivity to detect medium-to-large effects; post-hoc achieved power for the variables that reached significance ranged from 0.95 to 0.997 (Table 2), confirming that the principal analyses were not underpowered, although power for the small-effect variables (arm length, body fat) was lower (0.59–0.65). All participants were free of acute injury or illness, and players and guardians provided written informed consent. Procedures conformed to the Declaration of Helsinki.

Instruments and Measurements

Standing height and segmental lengths were recorded with a calibrated stadiometer and anthropometric tape to the nearest 0.1 cm. Limb girths (thigh, calf) were taken with a flexible non-elastic tape at the maximal relaxed circumference. Skinfolds at seven sites (biceps, triceps, subscapular, suprailiac, abdominal, thigh, calf) were measured on the right side with a calibrated caliper in duplicate, retaining the mean. All measurements followed the standardised landmarking and technique that Stewart, Marfell-Jones, Olds, and de Ridder (2011) set out for ISAK, and a single trained assessor took every reading to hold down inter-observer error, with duplicate readings at each site kept to limit intra-observer technical error of measurement.

Reliability of Measurements

To control measurement error, each site was measured twice within the same session and the mean of the duplicates was used in analysis, in keeping with ISAK practice. Reliability was judged against the established ISAK acceptability criteria rather than recomputed here, because the analysis dataset retained only the averaged value for each participant rather than the separate replicate readings needed to derive sample-specific indices. The relevant benchmarks are well documented: ISAK specifies that intra-tester technical error of measurement (TEM) should fall below 5% for skinfolds and below about 1–2% for lengths and girths, with a coefficient of reliability (R) above 0.95 (Esparza-Ros, Vaquero-Cristóbal, & Marfell-Jones, 2019; Perini et al., 1999). Studies using accredited anthropometrists report intra-evaluator TEM of roughly 1% for skinfolds and well under 1% for basic dimensions (Cabrera de León et al., 2023), so the single-assessor, duplicate-reading procedure used here is consistent with acceptable precision. We note as a limitation that formal intraclass correlation and TEM were not derived in this sample, and we recommend a dedicated test–retest protocol that retains replicate readings for future studies.

Derived Variables

Two body-composition indices were derived. The sum of seven skinfolds (ΣSF) served as a composite raw indicator of subcutaneous adiposity. Relative body fat (%BF) was estimated using the youth-specific equation of Slaughter et al. (1988), %BF = 0.735 (triceps + calf) + 1.0, appropriate for adolescent males. Body mass was not recorded in this dataset; consequently, body mass index, fat mass, fat-free mass, and density-based or somatotype models could not be computed, and body composition was confined to skinfold-based indices (see Limitations).

Statistical Analysis

Data were summarised as mean ± standard deviation with standard error and 95% confidence intervals. Within-group residual normality was examined with the Shapiro–Wilk test and homogeneity of variance with Levene's test. A one-way multivariate analysis of variance (MANOVA), with the seven anthropometric and body-composition variables as a dependent set, first tested the overall district effect; Wilks' Lambda, the approximate F, Pillai's trace, and multivariate eta-squared are reported. Given a significant multivariate effect, univariate one-way ANOVA was conducted on each variable, with eta-squared (η^2; 0.01, 0.06, 0.14 denoting small, medium and large effects) and Tukey HSD post-hoc tests. To address the potential confounding of chronological age, a one-way ANCOVA with age as covariate was conducted on each variable significant in ANOVA, with partial eta-squared reported. Post-hoc achieved power was estimated from the observed effect sizes. Analyses were performed in Python (NumPy/SciPy); significance was set at $p < 0.05$.

Results

Assumption checks indicated that within-group residuals were approximately normal for most variables (Shapiro–Wilk $p > 0.05$), with minor departures for thigh and calf girth that the balanced ANOVA design tolerates; Levene's test supported homogeneity of variance for the principal linear variables, with ΣSF and body fat showing borderline heterogeneity ($p = 0.031$ and 0.049), noted as a minor caveat. The one-way MANOVA returned a significant overall district effect on the multivariate set of anthropometric and body-composition variables (Wilks' $\Lambda = 0.004$, approximate $F_{42,318} = 17.61$, $p < 0.001$; Pillai's trace = 2.17; multivariate $\eta^2 = 0.61$), justifying the univariate analyses that follow. Descriptive statistics with 95% confidence intervals appear in Table 1; the assumption, ANOVA and effect-size summary in Table 2; and the age-adjusted ANCOVA in Table 3. Figures 1–3 display the distributions and multivariate profiles.

Table 1. Descriptive statistics (Mean ± SD, SE) with 95% confidence intervals, by district.

Variable	District	N	Mean	SD	SE	95% CI
Height (cm)	BHU	12	174.92	8.85	2.554	169.3–180.5
	BLW	12	180.08	8.54	2.466	174.7–185.5
	Agra	12	177.92	6.84	1.975	173.6–182.3
	Pilibhit	9	174.33	8.14	2.713	168.1–180.6
	Gorakhpur	11	183.91	3.53	1.066	181.5–186.3
	GBN	12	186.75	9.84	2.840	180.5–193.0
	Varanasi	12	183.58	11.10	3.204	176.5–190.6

Variable	District	N	Mean	SD	SE	95% CI
	Total	**80**	**180.39**	**9.25**	**1.034**	**—**

Variable	District	N	Mean	SD	SE	95% CI
Leg length (cm)	BHU	12	101.67	6.00	1.734	97.8–105.5
	BLW	12	105.83	4.93	1.424	102.7–109.0
	Agra	12	108.42	5.99	1.730	104.6–112.2
	Pilibhit	9	105.89	6.47	2.157	100.9–110.9
	Gorakhpur	11	109.14	3.58	1.080	106.7–111.5
	GBN	12	113.83	6.32	1.825	109.8–117.8
	Varanasi	12	111.25	7.35	2.122	106.6–115.9
	Total	**80**	**108.07**	**6.83**	**0.764**	**—**

Variable	District	N	Mean	SD	SE	95% CI
Arm length (cm)	BHU	12	76.50	4.48	1.294	73.7–79.3
	BLW	12	75.50	4.03	1.165	72.9–78.1
	Agra	12	76.50	5.02	1.449	73.3–79.7
	Pilibhit	9	74.44	4.72	1.573	70.8–78.1
	Gorakhpur	11	76.91	2.98	0.899	74.9–78.9
	GBN	12	78.33	4.56	1.316	75.4–81.2
	Varanasi	12	79.83	5.54	1.599	76.3–83.3
	Total	**80**	**76.95**	**4.67**	**0.522**	**—**

Variable	District	N	Mean	SD	SE	95% CI
Thigh girth (cm)	BHU	12	52.17	5.29	1.527	48.8–55.5
	BLW	12	43.25	2.22	0.641	41.8–44.7
	Agra	12	46.50	5.28	1.525	43.1–49.9
	Pilibhit	9	44.11	4.14	1.379	40.9–47.3
	Gorakhpur	11	45.18	4.33	1.306	42.3–48.1
	GBN	12	46.67	3.45	0.995	44.5–48.9
	Varanasi	12	46.25	3.67	1.060	43.9–48.6
	Total	**80**	**46.40**	**4.85**	**0.542**	**—**

Variable	District	N	Mean	SD	SE	95% CI
Calf girth (cm)	BHU	12	37.25	2.99	0.863	35.4–39.1
	BLW	12	33.92	1.50	0.434	33.0–34.9
	Agra	12	35.83	3.71	1.072	33.5–38.2
	Pilibhit	9	33.44	3.28	1.094	30.9–36.0
	Gorakhpur	11	34.00	1.48	0.447	33.0–35.0
	GBN	12	37.08	2.15	0.621	35.7–38.5
	Varanasi	12	34.67	3.11	0.899	32.7–36.6

Variable	District	N	Mean	SD	SE	95% CI
	Total	**80**	**35.25**	**2.99**	**0.334**	**—**

Variable	District	N	Mean	SD	SE	95% CI
Σ Skinfolds (mm)	BHU	12	54.90	3.97	1.147	52.4–57.4
	BLW	12	54.76	3.88	1.119	52.3–57.2
	Agra	12	53.98	4.07	1.174	51.4–56.6
	Pilibhit	9	63.89	6.61	2.205	58.8–69.0
	Gorakhpur	11	57.40	4.06	1.225	54.7–60.1
	GBN	12	57.60	5.12	1.479	54.4–60.9
	Varanasi	12	59.92	7.60	2.194	55.1–64.8
	Total	**80**	**57.25**	**5.86**	**0.655**	**—**

Variable	District	N	Mean	SD	SE	95% CI
Body fat (%)	BHU	12	12.56	0.81	0.234	12.0–13.1
	BLW	12	12.50	0.80	0.232	12.0–13.0
	Agra	12	12.38	0.85	0.246	11.8–12.9
	Pilibhit	9	13.25	1.31	0.437	12.2–14.3
	Gorakhpur	11	12.11	0.79	0.237	11.6–12.6
	GBN	12	12.04	0.97	0.280	11.4–12.7
	Varanasi	12	12.53	1.45	0.418	11.6–13.4
	Total	**80**	**12.46**	**1.04**	**0.116**	**—**

Note. CI = 95% confidence interval for the group mean; SE = standard error. N: BHU 12, BLW 12, Agra 12, Pilibhit 9, Gorakhpur 11, GBN 12, Varanasi 12; Total 80.

Table 2. Assumption checks, one-way ANOVA, effect size (η^2), and post-hoc power**.**

Variable	Levene p	Shapiro p	F (6,73)	p	η^2	Power
Height	0.080	0.485	3.49	0.004	0.223	0.952
Leg length	0.227	0.821	5.37	<.001	0.306	0.997
Arm length	0.745	0.052	1.69	0.137	0.122	0.653
Thigh girth	0.740	0.019	5.57	<.001	0.314	0.997
Calf girth	0.118	0.035	3.70	0.003	0.233	0.963
Σ Skinfolds	0.031	0.482	4.67	<.001	0.278	0.990
Body fat %	0.049	0.487	1.50	0.192	0.109	0.591

Note. η^2 interpreted as small (0.01), medium (0.06), large (0.14). Power = post-hoc achieved power from the observed effect size.

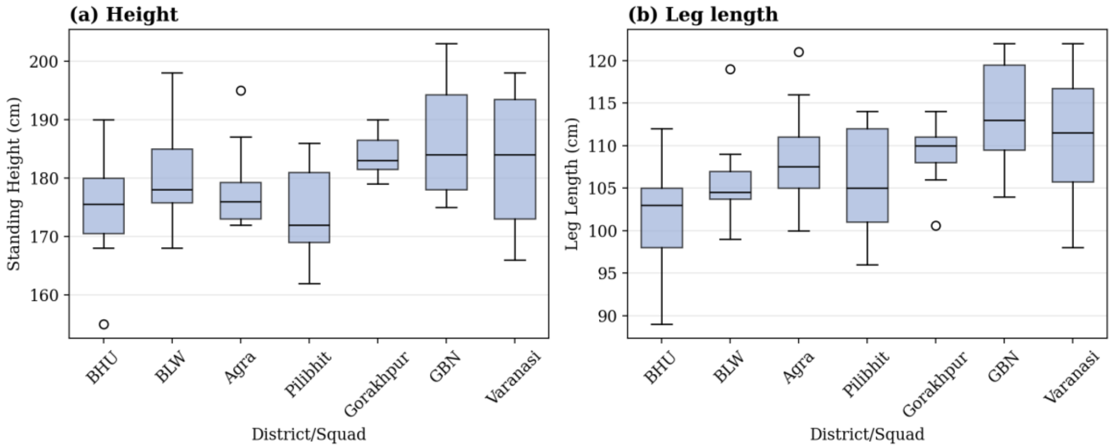
Table 3. Age-adjusted one-way ANCOVA (covariate = chronological age) for variables significant in ANOVA.

Variable	Adj. F	df	p (group)	Partial η^2	p (age cov.)
Height	3.48	6, 72	0.004	0.225	0.673
Leg length	5.48	6, 72	<.001	0.313	0.377
Thigh girth	6.87	6, 72	<.001	0.364	0.004

Variable	Adj. F	df	p (group)	Partial η²	p (age cov.)
Calf girth	3.74	6, 72	0.003	0.238	0.396
Σ Skinfolds	4.97	6, 72	<.001	0.293	0.207

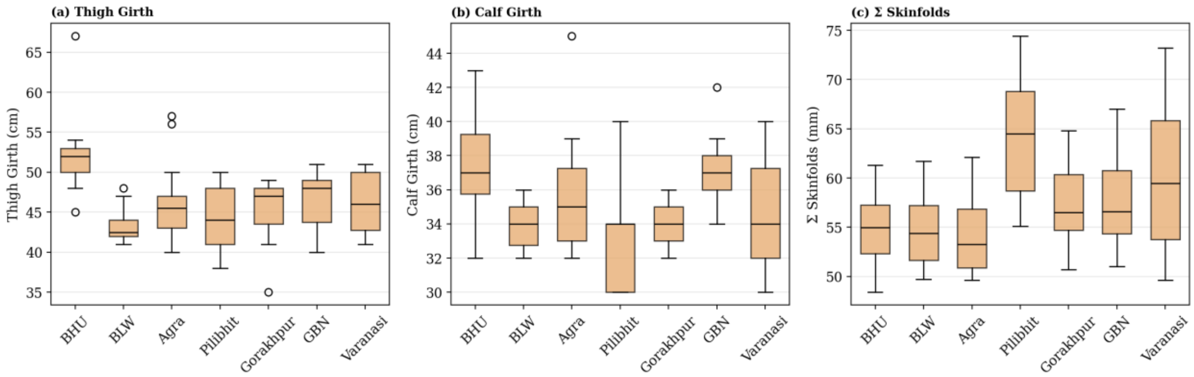
Note. Adj. F = age-adjusted group effect; partial η² = variance attributable to district after removing age; p (age cov.) tests the covariate.

Figure 1. Distribution of standing height and leg length across districts (box-and-whisker plots).



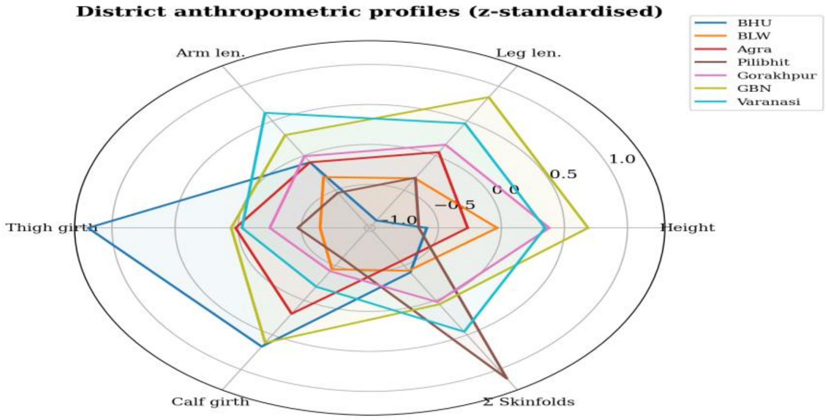
Boxes show interquartile range and median; whiskers show range. GBN displays the highest median for both variables.

Figure 2. Distribution of thigh girth, calf girth, and the sum of seven skinfolds across districts.



BHU shows the highest thigh-girth median; Pilibhit shows the highest Σ skinfolds.

Figure 3. Multivariate district profiles of six anthropometric variables (z-standardised means).



Each axis is standardised to the pooled sample (mean = 0, SD = 1). The radial spikes summarise the MANOVA effect: GBN/Varanasi extend on height and leg length, BHU on thigh girth, and Pilibhit on Σ skinfolds.

Anthropometric Dimensions

Standing height averaged 180.39 ± 9.25 cm and differed significantly among districts ($F_{6,73} = 3.49$, $p = 0.004$, $\eta^2 = 0.22$, a large effect). Tukey HSD localised the effect to the GBN squad, which was significantly taller than BHU ($\Delta \approx 11.8$ cm, $p = 0.017$) and Pilibhit ($\Delta \approx 12.4$ cm, $p = 0.023$). Leg length (108.07 ± 6.83 cm) showed the largest univariate effect ($F_{6,73} = 5.37$, $p < 0.001$, $\eta^2 = 0.31$): BHU players had significantly shorter legs than GBN ($p < 0.001$), and Varanasi ($p = 0.003$), and GBN also exceeded BLW and Pilibhit. Arm length (76.95 ± 4.67 cm) did not differ significantly ($p = 0.137$, $\eta^2 = 0.12$), indicating greater uniformity of upper-limb length than lower-limb length across squads (Figure 1).

Lower-Limb Girths

Thigh girth (46.40 ± 4.85 cm) varied significantly ($F_{6,73} = 5.57$, $p < 0.001$, $\eta^2 = 0.31$), driven almost entirely by the BHU squad, whose values exceeded those of every other squad (all $p < 0.05$; largest contrast versus BLW, $\Delta \approx 8.9$ cm, $p < 0.001$). Calf girth (35.25 ± 2.99 cm) likewise differed ($F_{6,73} = 3.70$, $p = 0.003$, $\eta^2 = 0.23$), with BHU and GBN exceeding the slim-calved Pilibhit squad (Figure 2).

Body Composition

The sum of seven skinfolds (57.25 ± 5.86 mm) differed significantly ($F_{6,73} = 4.68$, $p < 0.001$, $\eta^2 = 0.28$); Pilibhit recorded the highest mean (≈ 63.9 mm) and differed from BHU, BLW, and Agra (all $p \leq 0.003$). In contrast, the youth-specific Slaughter estimate of relative body fat (12.46 ± 1.04%) did not differ significantly ($p = 0.192$, $\eta^2 = 0.11$). Because that equation weights only the triceps and calf sites, the divergence implies that inter-district variation in subcutaneous fat resided largely in trunk and other limb depots not captured by the equation, while the appendicular sites it uses were comparable, which is exactly why Jagim et al. (2023) urge that the raw sum and the equation-derived percentage be read together.

Age-Adjusted Analysis

Although the squads differed in mean age (ANOVA $F_{6,73} = 8.62$, $p < 0.001$), the ANCOVA demonstrated that every significant district difference persisted after adjustment for chronological age: height (adj. $F_{6,72} = 3.48$, $p = 0.005$, partial $\eta^2 = 0.23$), leg length (adj. $F = 5.48$, $p < 0.001$, partial $\eta^2 = 0.31$), thigh girth (adj. $F = 6.87$, $p < 0.001$, partial $\eta^2 = 0.36$), calf girth (adj. $F = 3.74$, $p = 0.003$, partial $\eta^2 = 0.24$) and ΣSF (adj. $F = 4.97$, $p < 0.001$, partial $\eta^2 = 0.29$). The covariate itself was a significant predictor only for thigh girth ($p = 0.004$). These results indicate that the inter-district differences were not a maturational artefact of the age imbalance, but reflect district-level variation independent of chronological age.

Discussion

This study set out to learn whether adolescent male basketball players gathered from seven districts of Uttar Pradesh differ in their anthropometric and body-composition profiles, and—answering two complaints that dog much of the youth literature—whether any such differences survive both a multivariate test and an adjustment for age. The answer on both counts is yes. The overall district effect was very large (multivariate $\eta^2 = 0.61$), the linear measures and lower-limb girths varied with large univariate effect sizes, and those differences held up once age was controlled. Arm length and the position-relevant estimate of body fat, by contrast, looked much the same everywhere.

Why Are the GBN Players Taller and Longer-Legged?

GBN players stood out as taller and longer-legged than their BHU and Pilibhit counterparts, and because the gap remained after adjusting for age, it cannot simply be that the GBN boys were older. Three explanations, none mutually exclusive, seem plausible. The first is selection. Gautam Buddh Nagar sits inside the National Capital Region, where deeper talent pools and better-funded academies let selectors lean hard on height—the trait basketball recruiters prize above almost any other, as Drinkwater et al. (2008) and Han et al. (2023) have documented. When you can choose from more candidates, you keep the tallest, and squad height climbs regardless of the wider population. The second is the growth environment: gains in stature follow better nutrition and lower childhood illness, and Malina et al. (2004) noted that more urbanised, better-off settings tend to raise taller youngsters. The third is proportion and genetics. It is telling that the effect sat in leg length rather than arm length, because the legs contribute so much to standing reach and to the jump, and segmental proportions are partly inherited; Sodhi (1980) and Bandyopadhyay (2007) recorded just this kind of regional patterning among Indian athletes. The simplest reading folds selection on height together with a kinder growth environment in this particular district.

Why Is BHU Thigh Girth Higher?

The BHU squad carried noticeably thicker thighs than anyone else, and this was the single variable for which age mattered as a covariate—yet the district effect grew stronger, not weaker, after adjustment, which argues for a real morphological difference rather than an age artefact. Girth is a handy stand-in for regional muscularity, the tissue most heavily taxed by jumping and cutting, as Reilly et al. (2000) and Lukonaitiene et al. (2022) have pointed out. The likeliest culprit is how the squad trains. A programme that leans on lower-body resistance and plyometric work will build thigh muscle in a way a more skills- or endurance-focused regimen will not, and that is exactly the dissociation seen here: heavy thighs on a squad of otherwise middling height. It probably helps, too, that the BHU players were among the leanest in the sample, so whatever muscle they carry shows more plainly through thin subcutaneous fat. With body mass and any direct muscle measure missing, this account stays provisional and would need mass-inclusive or imaging methods to confirm.

Body Composition and the ΣSF–%BF Dissociation

The composition results turn on a useful puzzle. The raw sum of skinfolds varied a good deal—Pilibhit highest, BHU, BLW, and Agra lowest—yet the Slaughter estimate of relative fat did not budge between districts. Since that equation reads only the triceps and calf, the variation in subcutaneous fat must be living in the trunk and other depots that the formula never touches. Pilibhit's signature—plenty of skinfold fat on an otherwise lean, shorter frame—may point to a more rural setting with a different everyday diet and lighter training, though without food and load data, that remains a guess. The sample's overall figure of roughly 12% fat sits comfortably alongside what others report for trained youth: Ljubojevic et al. (2023) found 12.2% in junior Euroleague players, and Toselli et al. (2020) and Jagim et al. (2023) describe similarly favourable profiles. The lesson is the one Jagim et al. (2023) and Devrim-Lanpir et al. (2021) keep pressing—read the raw sum and the equation-derived percentage together, because equations built on non-athletes misfire in growing athletes.

Nutrition, Selection, and Regional Training Together

Pull the threads together, and a coherent story appears, woven from three regional strands. Nutrition and the growth environment most likely set the height gradient, with more urban districts turning out taller cohorts. Selection then sharpens that gradient wherever a large talent pool lets recruiters retain the tallest and longest-limbed, as is plausible for the National Capital Region squad. And the local training culture—how much it favours resistance and plyometric work over skill and conditioning—best explains the girth dissociation, the BHU thigh being the clearest case. A cross-sectional design that measures only anthropometry cannot isolate any one strand, but their combination offers a testable account of the district structure and squares with the multifactorial models of basketball talent advanced by Han et al. (2023) and Čaušević et al. (2026).

Maturation and the Value of Age Adjustment

One of this study's real contributions is taking the maturation problem head-on. Maturity weighs heavily on youth basketball morphology—early maturers are taller and more muscular than same-aged late maturers, as Čaušević et al. (2026) and Arede et al. (2021) have shown. Because the squads here differed in mean age, an unadjusted analysis would have been open to the obvious objection that the differences were really about age. The ANCOVA closes that door: every significant effect survived adjustment, and age earned its keep as a covariate for only one variable. That lends weight to a regional reading—growth environment, nutrition, training, selection—over an age-driven one, while conceding that chronological age is a rough proxy for biological maturity and that a maturity-offset calculation would have needed sitting height and body mass we did not collect.

Practical Implications

For coaches, selectors, and physical educators, these multivariate, age-adjusted reference values argue against forcing a single morphological template onto every district. The sturdy variation in height and lower-limb muscle suggests tailoring talent work to local reality—making the most of GBN's long levers or BHU's leg strength—while the even, healthy fat profile across squads points to sound general conditioning. Where a squad like GBN is picked mainly for height, some extra lower-body strength work would not go amiss; where a squad like BHU already has powerful thighs, sharpening linear speed and skill may pay off more.

Limitations and Future Directions

A few limitations frame these findings. The single most consequential limitation is the absence of body mass. Without it, body-mass index, absolute fat mass, fat-free mass, and the density-based and somatotype models that reviewers and selectors increasingly expect could not be computed, so the body-composition picture rested on skinfold indices alone and is necessarily partial; the thigh-girth interpretation in particular would be far firmer if expressed relative to mass or lean tissue. We therefore read the present composition findings as a screening-level description rather than a definitive body-composition profile, and we regard the addition of body mass—and, ideally, a criterion method such as DXA or bioimpedance—as the priority for any extension of this work. No performance tests—vertical jump, sprint, change-of-direction, or intermittent endurance—were taken either, so this remains a morphological description rather than a performance model, and pairing a field-test battery with anthropometry, as Han et al. (2023) advocate, would lift its applied value considerably. Playing position and training history were unavailable, though both shape the physique in basketball. The squads were modest and a little uneven in size, which trimmed power for the small-effect variables, and the skinfold sum and body-fat estimate showed borderline variance heterogeneity. Age served as the maturity proxy because the sitting height and mass needed for a maturity-offset estimate were not on hand. Reliability statistics—intraclass correlation and technical error of measurement—were not formally derived, since only duplicate within-session readings were kept; a proper test–retest protocol is the obvious next step. Finally, a single-state, cross-sectional snapshot limits causal and national claims. Longitudinal, maturity-controlled, position-stratified, multi-state work that folds in body mass, performance testing, and a criterion method such as DXA or bioimpedance would put the question on much firmer footing.

Conclusion

This study compared selected anthropometric and body-composition characteristics among adolescent male basketball players from seven districts of Uttar Pradesh using a multivariate framework and, uniquely for this literature, verified the findings against chronological age. A very large overall district effect was confirmed by MANOVA; significant univariate variation, with large effect sizes, was confined to stature, leg length, thigh and calf girths, and the raw sum of skinfolds, and every one of these effects persisted after age adjustment, while arm length and equation-derived relative body fat were homogeneous. The GBN squad was distinguished by superior height and limb length—plausibly through selection and a favourable growth environment—the BHU squad by greater lower-limb girth—plausibly through training emphasis—and the Pilibhit squad by the highest subcutaneous adiposity within an otherwise lean build, while the sample as a whole exhibited a favourable relative-fat profile. These multivariate, age-adjusted baseline values support region-sensitive talent identification and conditioning, and the limitations identified—particularly the absence of body mass, performance testing, and direct maturity assessment—define clear priorities for subsequent research

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