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Artículo original

Independent age-group differences versus longitudinal anthropometric changes in male adolescents aged 16–18 years: an exploratory pilot study

Diferencias antropométricas entre grupos de edad independientes frente a cambios longitudinales en adolescentes varones de 16 a 18 años: un estudio piloto exploratorio

Nderim Rexhepi[1,2] (Lead author); Urata Rexhepi[1,2]; Behlul Brestovci[1]; Agron M. Rexhepi[1,2]*

[1]Institute of Sports Anthropology, Prishtina, Kosovo;
[2]QSFN Corpore Sano, Prishtina, Kosovo.

***Corresponding author:** Agron M. Rexhepi. Institute of Sports Anthropology / QSFN Corpore Sano, Prishtina, Kosovo. Email: agronmrexhepi@gmail.com

ABSTRACT

Introduction: Independent age-group contrasts can describe age-related anthropometric patterns, but they do not measure within-individual change and may also reflect cohort composition and calendar time. Objective: To describe how far a non-contemporaneous independent age-group contrast diverged numerically from longitudinal change observed within the same cohort over a similar age interval in one institutional sample. Methods: In this exploratory pilot study, 27 male boarding-school students were followed from May 2023 to April 2025, and an independent group of 22 students recorded as approximately 18 years of age was assessed in April 2024. Body height, body weight, seven skinfolds, body mass index, and secondary estimated body-composition indicators were evaluated. Results: Mean longitudinal increases were 3.69 cm for body height and 6.36 kg for body weight, whereas the corresponding independent age-group differences were 4.44 cm and 14.18 kg. The discrepancy was 0.75 cm for body height (95% confidence interval −3.38 to 4.88) and 7.81 kg for body weight (−3.06 to 18.69). Chest skinfold showed the largest standardised

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difference between the two approximately 18-year-old groups. Conclusions: Because the independent age-group difference and longitudinal change shared the same baseline mean, their discrepancy is algebraically equivalent to the direct difference between those two older groups and cannot isolate effects of study design from cohort, maturation, or calendar-time effects. These results therefore provide an exploratory demonstration that independent age-group contrasts may differ from observed within-individual change; they do not evaluate comparative validity or equivalence of the two designs. The small class-based sample limits precision and generalisability.

Keywords: Adolescent; Adolescent Development; Anthropometry; Body Composition; Body Height; Cross-Sectional Studies; Longitudinal Studies; Skinfold Thickness

RESUMEN

Introducción: Los contrastes entre grupos de edad independientes describen patrones antropométricos relacionados con la edad, pero no miden el cambio intraindividual y pueden reflejar la composición de las cohortes y el tiempo calendario. Objetivo: Describir en qué medida un contraste no contemporáneo entre grupos de edad independientes difirió numéricamente del cambio longitudinal observado en la misma cohorte durante un intervalo etario similar. Métodos: Estudio piloto exploratorio en el que 27 estudiantes varones internos fueron seguidos entre mayo de 2023 y abril de 2025, y un grupo independiente de 22 estudiantes registrados con edad aproximada de 18 años fue evaluado en abril de 2024. Se midieron estatura, peso corporal, siete pliegues cutáneos, índice de masa corporal y estimaciones secundarias de composición corporal. Resultados: Los incrementos longitudinales medios fueron 3,69 cm (estatura) y 6,36 kg (peso corporal), frente a diferencias entre grupos de edad de 4,44 cm y 14,18 kg. La discrepancia fue de 0,75 cm para la estatura (intervalo de confianza del 95 %: −3,38 a 4,88) y de 7,81 kg para el peso corporal (−3,06 a 18,69). El pliegue cutáneo pectoral mostró la mayor diferencia estandarizada entre los dos grupos de aproximadamente 18 años. Conclusiones: Dado que la diferencia entre grupos de edad y el cambio longitudinal compartían la misma media basal, su discrepancia equivale algebraicamente a la diferencia directa entre esos dos grupos de mayor edad y no permite aislar los efectos del diseño de los efectos de cohorte, maduración o tiempo calendario. Estos resultados constituyen una demostración exploratoria de que los contrastes entre grupos de edad independientes pueden diferir del cambio intraindividual observado; no evalúan la validez comparativa ni la equivalencia de ambos diseños. El pequeño tamaño de la muestra basada en clases limita la precisión y la generalización.

Palabras clave: Adolescente; Desarrollo del Adolescente; Antropometría; Composición Corporal; Estatura; Estudios Transversales; Estudios Longitudinales; Grosor de los Pliegues Cutáneos

INTRODUCTION

Physical growth during adolescence reflects interacting genetic, hormonal, nutritional, environmental and behavioural influences. In males, linear growth generally decelerates after peak height velocity, while body weight and body composition may continue to change through late adolescence. Chronological age is an imperfect proxy for biological maturity, so individuals of the same age can differ substantially in their stage and tempo of development [1–4].

Longitudinal and independent age-group approaches answer related but distinct questions. Longitudinal studies measure change within the same individuals and therefore directly quantify within-person development over a defined interval. Independent age-group comparisons describe differences between groups whose members may differ in maturation, body composition, lifestyle and other characteristics unrelated to age itself [5,6]. When the groups are also assessed in different calendar periods, cohort composition and calendar-time influences are additionally inseparable from the age-group contrast. Consequently, a between-group age difference should not automatically be interpreted as the change that would have occurred within the same individuals.

The degree of correspondence between the between-group age differences and longitudinal change may also be characteristic-specific. Body height is a relatively stable cumulative measure, whereas body weight and adiposity are more sensitive to behavioural, nutritional and maturational variation. Body mass index combines height and weight but does not distinguish fat from fat-free tissue, which may further complicate interpretation during adolescence [7–9].

The present setting provided an opportunity to illustrate this issue under relatively homogeneous institutional conditions because participants attended the same secondary school and resided in the same boarding facility following broadly similar routines. This contextual homogeneity cannot establish comparability between classes or remove biological, behavioural, cohort or calendar-time differences, but it reduces some obvious sources of environmental heterogeneity. The narrower knowledge gap addressed here is therefore descriptive: how far a non-contemporaneous independent age-group contrast in this particular institutional sample differed numerically from observed within-individual change, and whether the magnitude of that divergence varied across anthropometric characteristics.

The primary objective of this exploratory pilot study was to describe the numerical divergence between an independent age-group contrast involving male adolescents recorded at approximately 16 and 18 years and anthropometric change observed longitudinally over approximately 23 months. The study was not designed to evaluate the comparative validity or accuracy of cross-sectional and longitudinal designs, to estimate population growth

standards, or to establish statistical equivalence. We anticipated that the magnitude of the numerical discrepancy would vary across anthropometric characteristics and would be smaller for body height than for body weight and body-composition-related measures.

MATERIALS AND METHODS

Study design and participants

This pilot observational study combined a longitudinal cohort with an independent, non-contemporaneous age-group comparison. Participants were male students attending the "Alauddin Madrasa" Secondary School in Prishtina, Kosovo, and residing in the boarding facility within the school premises. Two intact classes were included as class-based convenience samples rather than by random sampling. The archived analytic records do not document additional class-level selection criteria. One class formed the longitudinal cohort and was scheduled for four measurement rounds; a second class formed the independent comparison group and was assessed once. The longitudinal cohort progressed from Grade 10 at baseline to Grade 12 at the final assessment. For the longitudinal analysis, inclusion required complete anthropometric records at all four scheduled rounds. Students with a missing scheduled measurement were removed before construction of the final analytic register. The retained longitudinal dataset therefore contained 27 complete cases, and the independent comparison dataset contained 22 complete cases. No additional exclusions were made after the final analytic datasets were assembled. Because the archived analytic files contain only the complete cases retained for analysis, the initial class rolls and total numbers eligible or enrolled before exclusion are not preserved in the analytic register; therefore only the final complete-case counts can be reported reliably.

Measurements in the longitudinal cohort were conducted on 1 May 2023, 1 April 2024, 1 December 2024 and 1 April 2025. The primary longitudinal comparison used the seasonally comparable baseline and final assessments, separated by 701 days (approximately 23 months). Only the year of birth was recorded; age was calculated as assessment year minus birth year and is therefore reported as nominal calendar-year age rather than exact chronological age. One participant born in 2008 was 15 years old at baseline and 17 years old at the final assessment. Mean nominal age was 16.15 ± 0.46 years (range 15–17) at baseline and 18.15 ± 0.46 years (range 17–19) at the final assessment. The independent comparison group comprised 22 participants assessed on 30 April 2024, with recorded age 18.14 ± 0.47 years (range 17–19). No formal a priori sample-size calculation was performed because the study was conceived as an exploratory pilot based on intact school classes; the resulting samples were therefore convenience samples rather than representative samples of the wider adolescent population.

The observations used to construct the independent age-group contrast were not obtained concurrently: the longitudinal baseline was measured in May 2023 and the independent older group in April 2024. Likewise, the independent group at approximately 18 years was assessed in April 2024, whereas the longitudinal cohort reached its final approximately 18-year assessment in April 2025. The independent-group contrast is therefore described as a non-contemporaneous, cross-sectional-type age-group comparison rather than a conventional single-time-point cross-sectional survey. Calendar-time, cohort-composition and unmeasured maturation or behavioural effects cannot be separated from the observed between-group differences.

Anthropometric measurements

Direct measurements comprised body height, body weight, and triceps, subscapular, chest, abdominal, suprailiac, thigh and calf skinfold thickness. Body mass index was calculated as body weight in kilograms divided by height in metres squared. Estimated body fat percentage was calculated with the four-site equation for males described by Jackson and Pollock [10]: % body fat = $(0.29288 \times S) - (0.0005 \times S^2) + (0.15845 \times A) - 5.76377$, where S is the sum (mm) of triceps, abdominal, suprailiac and thigh skinfolds and A is the nominal calendar-year age. Estimated fat mass was calculated as body weight × estimated body fat percentage / 100, and estimated fat-free mass as body weight minus estimated fat mass. The equation was developed for adults and was not specifically validated for the full adolescent age range represented in this study; contemporary reviews also emphasise the population- and age-specific nature of anthropometric prediction equations [11]. Consequently, estimated body fat percentage, fat mass and fat-free mass were treated as secondary exploratory indicators rather than direct measurements.

All measurements were performed by the same researcher in the same school setting. Participants were measured wearing only underwear, following International Biological Programme procedures [12]. For the seven recorded sites (triceps, subscapular, chest, abdominal, suprailiac, thigh and calf), anatomical landmarking and fold orientation followed the referenced IBP procedures; no study-specific alternative landmarking scheme was used. Siber-Hegner instruments (Zurich, Switzerland) were used throughout: body height was measured to 1 mm, body weight to 0.1 kg and skinfold thickness to 0.2 mm. The same instruments were used at all measurement rounds and checked for consistent functioning before each assessment. A single value for each measurement was retained in the analytic field record at each visit; duplicate or repeat readings suitable for retrospective reliability estimation were not available. Formal intra-observer reliability and technical error of measurement were therefore not quantified and were not retrospectively inferred. This limitation is especially relevant to the interpretation of skinfold results, for which precise

landmarking, tissue handling and repeated quality-control measurements can materially affect reproducibility [13].

Participants in both groups shared broadly comparable institutional conditions, including accommodation, scheduled meals and daily routines. However, biological maturity, individual dietary intake, physical activity, sleep, socioeconomic characteristics and other potential between-class comparability factors were not formally assessed. The common institutional environment therefore provides contextual consistency but does not establish equivalence or comparability between the groups.

Statistical analysis

Continuous variables are presented as mean ± standard deviation. The primary longitudinal change (ΔL) was calculated as the mean final value of the longitudinal cohort minus its baseline mean. The independent age-group difference (ΔA) was calculated as the mean of the independent group recorded at approximately 18 years minus the baseline mean of the longitudinal cohort recorded at approximately 16 years. The discrepancy between the two quantities was defined as $D = \Delta A - \Delta L$. Because ΔA and ΔL share the same baseline mean, D is algebraically identical to the direct difference between the independent approximately 18-year group and the longitudinal cohort at its final assessment. D is therefore interpreted as a descriptive between-cohort difference at the older assessment, not as an estimate of bias, accuracy or comparative validity attributable to study design.

Within-participant baseline-to-final longitudinal change was analysed with paired-samples t-tests and conventional 95% confidence intervals. The discrepancy D was evaluated through the direct independent comparison of the two approximately 18-year groups using independent-samples t-tests; Welch's test was used when homogeneity of variance was not supported. Effect sizes were expressed as Cohen's dz for paired comparisons and Hedges' g for independent comparisons. Distributional assumptions were assessed using Shapiro–Wilk tests, Q–Q plots, skewness and kurtosis, and inspection for influential observations. The two intermediate longitudinal rounds were used to describe the trajectory of the cohort and are reported as descriptive statistics in Supplementary Table S1 rather than as additional primary inferential comparison families. Individual trajectories for body height, body weight and chest skinfold thickness are presented in Supplementary Figures S1–S3. Wilcoxon signed-rank and Mann–Whitney U tests were used as non-parametric sensitivity analyses; their principal results are reported in Supplementary Table S2.

To control the family-wise error rate across the 13 outcomes, p-values were adjusted using the sequential Holm procedure [14] separately for two prespecified inferential families: the baseline-to-final longitudinal comparisons and the direct comparison between the two approximately 18-year groups. Intermediate-round descriptive summaries were

not included in those inferential families. The confidence intervals reported in the main tables are conventional, unadjusted 95% intervals, whereas the accompanying p-values are Holm-adjusted; the two summaries therefore need not yield identical significance decisions. Statistical significance was defined as adjusted $p < 0.05$, but interpretation emphasised effect estimates, confidence-interval width and biological plausibility rather than significance testing alone. Analyses were performed using IBM SPSS Statistics version 21; revision-stage numerical checks were independently reproduced from the archived analytic datasets.

Ethical considerations

The study protocol was approved by the Ethics Committee of the Institute of Sports Anthropology, Prishtina, Kosovo, before data collection (Protocol No. 133/2023, 13 April 2023). Institutional permission was obtained from the Islamic Community of Kosovo and the administration of the "Alauddin Madrasa" Secondary School. Participation was voluntary. Written informed consent was obtained from all participants. For participants who were minors at enrolment, their own written agreement to participate was required together with written informed consent from a parent or legal guardian, in accordance with the approved protocol. Participant data were coded and de-identified before analysis. The study was conducted in accordance with the Declaration of Helsinki.

RESULTS

Sample characteristics and longitudinal change

The retained longitudinal analytic sample comprised 27 complete cases with data at all four measurement rounds, and the independent comparison sample comprised 22 complete cases. No further exclusions occurred after the final analytic datasets were assembled. Students with incomplete longitudinal measurement sequences had been removed before finalisation of the archived analytic register; consequently, their number is not recoverable from the retained analytic file. No participant characteristics beyond recorded age and the anthropometric variables were available for formal between-class comparability assessment. Descriptive values at the longitudinal baseline and final assessment and in the independent approximately 18-year group are shown in Table I.

Table I.

Descriptive anthropometric characteristics of the longitudinal cohort at baseline and final assessment and of the independent age-18 group

Variable	Longitudinal baseline ≈16 years (n=27)	Longitudinal final ≈18 years (n=27)	Independent group ≈18 years (n=22)
Body height (cm)	175.43 ± 8.79	179.12 ± 7.43	179.87 ± 6.79
Body weight (kg)	65.92 ± 17.00	72.28 ± 17.69	80.10 ± 20.13
Triceps skinfold (mm)	8.83 ± 4.40	13.43 ± 6.25	12.27 ± 5.57
Subscapular skinfold (mm)	8.64 ± 6.53	10.35 ± 7.76	11.99 ± 7.01
Chest skinfold (mm)	2.79 ± 1.12	5.74 ± 2.25	3.03 ± 1.41
Abdominal skinfold (mm)	15.07 ± 12.27	13.70 ± 11.82	20.72 ± 13.43
Suprailiac skinfold (mm)	13.17 ± 10.39	12.22 ± 11.06	19.78 ± 10.75
Thigh skinfold (mm)	17.53 ± 12.90	20.27 ± 13.73	22.53 ± 13.10
Calf skinfold (mm)	11.41 ± 5.83	12.61 ± 7.40	12.90 ± 7.28
Body mass index (kg/m²)	21.31 ± 4.55	22.47 ± 4.73	24.63 ± 5.41
Estimated body fat (%)	10.62 ± 7.82	11.98 ± 7.78	15.52 ± 8.52
Estimated fat mass (kg)	8.06 ± 8.80	9.88 ± 10.30	13.79 ± 10.38
Estimated fat-free mass (kg)	57.86 ± 9.49	62.40 ± 8.17	66.31 ± 11.08

Values are mean ± standard deviation. Body height, body weight, and skinfolds were measured directly; body mass index was calculated from height and weight; body fat percentage, fat mass, and fat-free mass are equation-derived estimates.

Over approximately 23 months, mean body height increased by 3.69 cm (95% confidence interval (CI) 2.49 to 4.89), body weight by 6.36 kg (95% CI 4.56 to 8.17), body mass index by 1.16 kg/m² (95% CI 0.67 to 1.65), and estimated fat-free mass by 4.55 kg (95% CI 3.23 to 5.87); these four baseline-to-final changes remained statistically significant after Holm adjustment. Estimated body fat percentage increased by 1.36 percentage points and estimated fat mass by 1.81 kg, but neither change remained statistically significant in the primary Holm-adjusted paired analyses. Descriptive statistics for all four longitudinal rounds are provided in Supplementary Table S1, and individual trajectories for body height, body weight and chest skinfold thickness are shown in Supplementary Figures S1–S3. The intermediate rounds are presented descriptively rather than as separate primary inferential comparisons.

Independent age-group difference versus longitudinal change

The numerical discrepancy between the independent age-group contrast and longitudinal change varied across variables (Table II). For body height, the independent age-group difference was 4.44 cm compared with a longitudinal change of 3.69 cm, yielding D = 0.75 cm (95% CI −3.38 to 4.88; Hedges' g = 0.10). The small point estimate was accompanied by a wide confidence interval and therefore does not establish similarity or equivalence. For body weight, the independent age-group difference was 14.18 kg compared with a longitudinal change of 6.36 kg; D was 7.81 kg (95% CI −3.06 to 18.69; g = 0.41).

For body mass index and the secondary estimated body-composition indicators, the independent age-group differences were also numerically larger than the corresponding longitudinal changes, although confidence intervals were wide. For abdominal and suprailiac skinfolds, the independent age-group difference and longitudinal change were in opposite directions. Chest skinfold thickness showed the largest standardised direct difference between the two approximately 18-year groups: the longitudinal increase was 2.95 mm, whereas the independent age-group difference was 0.23 mm, resulting in D = −2.71 mm (95% CI −3.78 to −1.65; Holm-adjusted $p < 0.001$; g = −1.39). The overall descriptive interpretation remained when attention was restricted to directly measured anthropometric variables. In non-parametric sensitivity analyses (Supplementary Table S2), chest skinfold remained strongly different after Holm adjustment, and suprailiac skinfold also reached the adjusted threshold (pHolm = 0.048) in the comparison of the two approximately 18-year groups; the remaining independent-group sensitivity comparisons did not. The paired non-parametric sensitivity analysis yielded a Holm-adjusted p-value of 0.048 for estimated body fat percentage (Supplementary Table S2), whereas the primary parametric analysis was not statistically significant.

Because recorded age is included in the Jackson–Pollock equation, an additional equation-level sensitivity calculation was performed to illustrate the contribution of the age term. Holding the age term at each participant's baseline recorded age while allowing the observed skinfolds and body weight to change reduced the mean estimated body-fat increase from 1.36 to 1.05 percentage points and the estimated fat-mass increase from 1.81 to 1.59 kg; the corresponding estimated fat-free-mass increase changed from 4.55 to 4.78 kg (Supplementary Table S3). This calculation is descriptive and does not validate the equation in adolescents, but it demonstrates that part of the apparent change in the derived indicators is mathematically introduced by the age term itself.

Table II.

Longitudinal change and non-contemporaneous independent age-group difference across approximately 16–18 years

Variable	Longitudinal change ΔL [95% CI]	Age-group difference ΔA	Discrepancy D=ΔA−ΔL [95% CI]	Hedges' g	pHolm for D
Body height (cm)	3.69 [2.49, 4.89]	4.44	0.75 [−3.38, 4.88]	0.10	1.000
Body weight (kg)	6.36 [4.56, 8.17]	14.18	7.81 [−3.06, 18.69]	0.41	1.000
Triceps skinfold (mm)	4.60 [2.30, 6.90]	3.44	−1.16 [−4.60, 2.28]	−0.19	1.000
Subscapular skinfold (mm)	1.70 [0.79, 2.62]	3.35	1.64 [−2.65, 5.94]	0.22	1.000
Chest skinfold (mm)	2.95 [2.01, 3.89]	0.23	−2.71 [−3.78, −1.65]	−1.39	<0.001
Abdominal skinfold (mm)	−1.38 [−4.01, 1.25]	5.64	7.02 [−0.24, 14.28]	0.55	0.634
Suprailiac skinfold (mm)	−0.95 [−2.85, 0.95]	6.61	7.56 [1.25, 13.87]	0.68	0.239
Thigh skinfold (mm)	2.73 [−0.91, 6.37]	4.99	2.26 [−5.51, 10.03]	0.17	1.000
Calf skinfold (mm)	1.21 [−0.05, 2.46]	1.49	0.29 [−3.96, 4.53]	0.04	1.000
Body mass index (kg/m²)	1.16 [0.67, 1.65]	3.32	2.16 [−0.75, 5.07]	0.42	1.000
Estimated body fat (%)	1.36 [−0.40, 3.12]	4.91	3.54 [−1.15, 8.23]	0.43	1.000
Estimated fat mass (kg)	1.81 [0.27, 3.36]	5.72	3.91 [−2.06, 9.88]	0.37	1.000
Estimated fat-free mass (kg)	4.55 [3.23, 5.87]	8.45	3.91 [−1.63, 9.44]	0.40	1.000

ΔL = mean final minus baseline value within the longitudinal cohort; ΔA = mean value in the independent approximately 18-year group minus the longitudinal baseline mean; D = ΔA − ΔL, algebraically equivalent to the direct difference between the two approximately 18-year groups. Confidence intervals are conventional unadjusted 95% intervals, whereas pHolm values are Holm-adjusted across the 13 outcomes in the direct older-group comparison. Hedges' g refers to the direct independent-group comparison.

DISCUSSION

This pilot study descriptively examined how a non-contemporaneous independent age-group contrast differed from within-individual longitudinal change over a similar age interval in one institutional sample. The numerical discrepancy was small for the point estimate of body height and larger for several other characteristics, particularly body weight and chest skinfold thickness. However, the wide confidence intervals for many discrepancies show that precision was limited by the small sample. The analysis should therefore be interpreted as an exploratory demonstration of divergence within this dataset, not as an assessment of the comparative validity or accuracy of cross-sectional and longitudinal designs.

Body height showed a small numerical point discrepancy: the independent age-group difference was 0.75 cm greater than the observed longitudinal change. Height is a cumulative and comparatively stable measure, and linear growth commonly decelerates during late male adolescence [1,3,4]. Nevertheless, the 95% confidence interval for the height discrepancy ranged from −3.38 to 4.88 cm. The present data therefore do not establish that the two estimates are sufficiently similar; the finding is descriptive only.

Body weight showed a different numerical pattern. The independent age-group difference was more than twice the observed longitudinal increase. Body weight reflects fat mass, fat-free mass, bone mass and body water and can be influenced by nutrition, physical activity, maturation and cohort composition [1,2]. Longitudinal evidence has also shown associations between physical activity and changes in lean body mass during adolescence [15]. Because biological maturity, individual diet, physical activity and sleep were not measured, and because the groups were assessed in different calendar years, the observed discrepancy cannot be attributed to any single mechanism or to study design itself.

A defining mathematical feature of the analysis is that both ΔL and ΔA use the same longitudinal baseline mean. Their difference therefore reduces exactly to the direct difference between the independent group assessed at approximately 18 years in April 2024 and the longitudinal cohort assessed at its final approximately 18-year examination in April 2025. Consequently, D cannot separate effects of observational design from cohort composition, biological maturation, calendar time or other unmeasured characteristics. The observed discrepancies should not be interpreted as general limitations or measurement bias of cross-sectional research; they describe differences between the specific groups and measurement periods available in this study.

The skinfold findings require particular caution. Chest skinfold thickness showed the largest standardised difference between the two older groups. The four-round descriptive data and individual trajectories (Supplementary Table S1 and Supplementary Figure S3) show that much of the longitudinal chest-skinfold increase occurred in the final interval and was not attributable to a single obvious extreme trajectory. Even so, skinfold measurements

are sensitive to anatomical landmarking, tissue handling and examiner technique, and contemporary reviews emphasise the importance of explicit standardisation and quality control [13]. The use of the same examiner and instruments across rounds reduces some variability, but the absence of duplicate readings, technical error of measurement and quantified intra-observer reliability prevents separation of biological change from possible measurement variability. The chest-skinfold result should therefore be treated as an exploratory signal rather than a definitive biological difference.

The equation-derived body-composition indicators require an additional layer of caution. The four-site Jackson–Pollock equation was developed for adults [10], whereas this study included participants recorded below 18 years at baseline. A recent scoping review identified substantial heterogeneity in anthropometric equations developed for children and adolescents and emphasised the importance of age- and population-appropriate validation [11]. Moreover, age enters the present prediction equation directly. The sensitivity calculation holding the age term constant showed that part of the longitudinal change in estimated body fat, fat mass and fat-free mass was mathematical rather than independently observed. For this reason, the conclusions of the study are based primarily on directly measured anthropometric variables, with the estimated body-composition outcomes retained only as secondary exploratory indicators.

The absence of statistically significant discrepancies for most variables does not demonstrate equivalence. With small groups and wide confidence intervals, a non-significant result can coexist with differences that may be biologically relevant. Formal equivalence testing would require prespecified acceptable margins, a sample size planned for that objective, and a design that more directly aligns the age groups and measurement periods.

Limitations and implications

The study has several limitations. The sample was small, class-based, male-only and drawn from one institution, which limits generalisability and estimation precision. The independent age-group contrast was non-contemporaneous, and the two approximately 18-year groups were assessed in April 2024 and April 2025, respectively. Although measurements were made in comparable spring periods and under similar institutional conditions, cohort and calendar-time effects cannot be excluded or separated from the observed between-group differences. The common boarding-school environment does not establish comparability between classes, and no formal baseline information on biological maturity, dietary intake, physical activity, sleep or socioeconomic characteristics was available.

Biological maturity was not assessed directly despite substantial inter-individual variation during late adolescence. Only birth year was recorded, so age was expressed in nominal calendar years rather than exact chronological age. Several skinfold variables were highly

variable, and formal measurement reliability or technical error could not be quantified because duplicate readings were not retained. The adult-derived body-composition equation also limits interpretation of estimated fat percentage, fat mass and fat-free mass in this age range. Non-parametric sensitivity analyses and the four-round descriptive presentation improve transparency, but they do not overcome the limited sample size or the non-contemporaneous cohort structure.

These limitations define the appropriate contribution of the study. The results should be viewed as a descriptive methodological illustration and a source of hypotheses for larger, purpose-designed research, not as population growth estimates or evidence that one observational design is more valid than another. Future studies should use larger samples, date-of-birth-derived decimal age where available, direct assessment of biological maturity, repeated anthropometric measurements for reliability assessment, age-appropriate body-composition methods, aligned measurement windows and, where feasible, concurrently assessed independent age groups.

Data Availability Statement

Participant-level data are not deposited in a public repository because the informed-consent and institutional approvals for this study did not permit unrestricted public release; consequently, no dataset DOI or persistent public URL is available. De-identified data supporting the reported findings may be made available by the corresponding author upon reasonable request, subject to approval by the relevant ethical and institutional authorities. Access is therefore controlled because of ethical and confidentiality restrictions.

CONCLUSIONS

In this exploratory pilot sample, the numerical difference between a non-contemporaneous independent age-group contrast and observed within-individual change varied across anthropometric characteristics. Body height had a small point discrepancy but a wide confidence interval, whereas larger numerical discrepancies were observed for body weight and selected skinfold measures. Because the two change quantities share the same baseline mean, their discrepancy is equivalent to the direct difference between the two approximately 18-year groups and cannot isolate study-design effects from cohort, maturation or calendar-time influences. The findings therefore do not establish equivalence, superiority or comparative validity of either design. They provide a descriptive demonstration that independent age-group contrasts in a particular sample need not reproduce within-individual longitudinal change. Larger, purpose-designed studies are required to quantify such relationships with adequate precision.

Conflict of Interest

The authors declare no conflict of interest.

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Use of Artificial Intelligence Tools

During manuscript preparation and revision, the authors used ChatGPT (OpenAI) to assist with language editing and numerical cross-checks. The authors take full responsibility for the study data, analyses and final content of the manuscript.

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Authorship Contribution

Nderim Rexhepi: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft.

Urata Rexhepi: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft.

Behlul Brestovci: Methodology, Formal analysis, Validation, Writing – review and editing.

Agron M. Rexhepi: Supervision, Validation, Methodology, Formal analysis, Project administration, Writing – review and editing.