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Short notice
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Latent Structure of Anthropometric Characteristics in Male Adolescents Aged 12–14: A Two-Wave Factor Analytical Study

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Abstract: *Understanding the latent structure of morphological characteristics in adolescents is essential for monitoring their growth, biological maturity and physical development. This study included a sample of 388 male students aged 12 to 14 years from three primary schools in Pristina, in order to identify the dominant latent dimensions that structure anthropometric variability at two time points – initial and final measurement. The applied set of anthropometric measures was processed by factor analysis using the principal components method with Varimax rotation, and the selection of components was performed according to the Kaiser–Gutmann criterion. Two stable and clearly interpretable dimensions were distinguished in both time sections: a body mass and subcutaneous fat tissue factor and a longitudinal dimensionality factor. The high percentage of explained variance and the consistency of the model in both measurements indicate a replicable morphological structure, characteristic of this developmental period. The obtained results have significant practical value, as they provide a valid basis for systematic growth monitoring, identification of risky anthropometric profiles and planning of interventions in the context of education and sports training.*

Keywords: *anthropometry, latent structure, adolescents, factor analysis, body mass, longitudinal dimensionality*

Introduction

Monitoring morphological development is a powerful indicator of health status in childhood, adolescence and adulthood (Ortega, et al. 2008). Even in children and adolescents, morphological development is negatively associated with cardiorespiratory diseases, high blood pressure (Sallis, et al. 1998; Ruiz, et al. 2006), abdominal adiposity (Brunet, et al. 2006), total obesity (Ruiz, et al. 2006; Ortega, et al. 2011), impaired skeletal health (Moliner-Urdiales, et al. 2010), hyperinsulinemia (Gutin, et al. 2004), insulin resistance (Gulati, et al. 2003), atherogenic lipid profile (Mesa, et al. 2006), and a number of metabolic risk factors (Brage, et al. 2004; Ruiz, et al. 2007).

Morphological development can be objectively and accurately measured through laboratory methods, but due to high cost, the need for sophisticated equipment, qualified professional staff, and time constraints, laboratory tests cannot yet be used at the population level. In contrast, field measurements and tests are easy to administer, involve minimal equipment, can test a large number of subjects simultaneously, and can be evaluated in a short period of time (Paineau, 2008; Rodriguez G., et al. 2005; Ruiz, et al. 2009). In the school environment, field tests and measurements are an economical and practical option for assessing the level of morphological development of students.

Based on the previously stated, as well as on previous research, the subject of this research is anthropometric measures, and the main goal is to determine the state of morphological development among male students from the upper grades of primary schools, aged 12 to 14 years (from 7th to 9th grade), who regularly attend physical education, sports and health classes.

To facilitate the interpretation of complex sets of anthropometric data, factor analysis is often used in scientific studies. This method condenses the entire set of manifest measures into a few latent dimensions (factors) that explain the variability in the data. For example, in modern anthropometry, four basic morphological dimensions are recognized: longitudinal dimension (bone growth in length), transverse dimension (growth in width), circular/volume dimension (total body volume), and dimension of body mass and subcutaneous fat. These four dimensions are often grouped in practice into two "large" factors, one that covers longitudinal and transverse dimensions (bone structure), and the second that covers body mass and fat. Research in kinesiological anthropometry shows that these latent dimensions are present across age groups. In adults, Momirović, K. (1969) found a four-dimensional model (longitudinal, transverse, circular and mass/fat), while in adolescents it often turns out to be simpler. In particular, Viskić-Štalec (1974) summarized adolescence with three main dimensions: skeletal dimensionality, volume/mass and subcutaneous fat.

Šćepanović and Protić-Gava (2013) found two key dimensions in 15-year-old boys: a mass and volume factor (weight and circumferences and thicknesses of folds) and a longitudinal dimensionality factor (body height and arm and leg length). These examples show that latent structures can vary: in some samples two factor dimensions appear, in others three, but they always reflect basic morphological profiles (growing skeleton, body with mass/volume and even distribution of fat tissue).

However, there are gaps in the literature. Previous factor studies have mostly focused on older adolescents or on single measurements (which do not test the consistency of the factor structure). The current state of the latent structure in young teenagers (12–14 years) has not yet been sufficiently examined, especially in the context of longer-term (longitudinal) observation. Unlike single-phase approaches, the two-phase design allows us to test whether these factors remain stable and replicable over time. Namely, as Popović et al. (2016) point out, during growth, each morphological measure may have a different share in the latent structure at different stages of development. Therefore, we need a second measurement to assess the repeatability of the extracted dimensions (i.e., the structural invariance of the factors).

Given the above, the main goal of this research is clear and focused: to determine the latent dimensions of anthropometric measures in male students from 7th to 9th grade (12–14 years old), who regularly attend physical education classes. In this context, "determining latent dimensions" means using factor analysis to identify the main factors that explain the morphological variation in the data. In addition, the design is longitudinal, two measurements were conducted (at the beginning and end of the school year) in order to check the stability of the factor structure over time and to confirm that the obtained dimensions are consistent and replicable. Also, based on the nature of scientific research (Bala, 2007), it falls into the category of empirical research and represents applied, i.e. applicative research aimed at acquiring new knowledge and information necessary for pedagogical practice in schools and beyond. These results will enable a better understanding of physical development in adolescents and will serve as a basis for later practical interventions in education and sports training.

Methods

The research was conducted in order to determine the latent dimensions of morphological characteristics in male students from the upper grades of primary education. The sample consists of a total of 388 students from three primary schools: OU "Nazim Gafuri", OU "Elena Gjika" and OU "Zelena Shkola" in the city of Pristina R. Kosovo, aged 12 to 14 years ± 6 months, who regularly attend classes in physical education, sports and health. The respondents are students from the 7th, 8th and 9th grades.

The research has a longitudinal design, with two measurements: the first (initial) was carried out at the beginning of the school year, while the second (final) was carried out at the end of the same school year.

To measure morphological characteristics, a standardized set of six anthropometric variables was used, selected based on the International Biological Program – IBP (Weiner & Lourie, 1981), which is a reference methodology in the field of biological anthropology and physical education (Bala, 2007). The variables are grouped into the following subdimensions:

- Longitudinal dimensionality of the skeleton
  - Body height (ATLVIS)
- Body mass and volume
  - Body weight (ATLMAS)
  - Abdominal circumference (AOBTRB)
- Subcutaneous fat
  - Upper arm skinfold (ANABNA)
  - Back skinfold (ANABLE)
  - Subcutaneous fat index (BMI)

To determine the latent structure of the applied manifest variables, the Hotaling method of principal components was used. The selection of significant factors was made according to the Kaiser-Gutmann criterion, i.e. factors with an eigenvalue greater than 1. Varimax orthogonal rotation was applied to increase the interpretability of the obtained components. All statistical processing was carried out in the SPSS 26.0 statistical package. The level of statistical significance in the analysis was set at $p \leq 0.05$.

Results

Based on the intercorrelation matrix of the applied manifest variables of morphological characteristics, the characteristic roots (lambda) were obtained, which explain the common variance of each isolated principal component in the first-order space (table no. 1). The applied Guttman-Kaiser criterion extracted 2 significant latent dimensions. The first of them with an eigenvalue (total=3.822) explains 63.706% of the total variance of the variables, the second with a value (total=1.691) explains 28.184% of the total variance. The total explained variance by the extracted latent dimensions amounts to 91.890% of the common variance of the entire system and seems to be sufficient for the explication of the variability and covariability of the manifest variables applied to the student sample.

Table 1. *Factor Analysis Results -Total variance explained in the initial measurement*

Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.344	72.403	72.403	4.344	72.403	72.403	3.822	63.706	63.706
2	1.169	19.487	91.890	1.169	19.487	91.890	1.691	28.184	91.890
3	0.225	3.756	95.646						
4	0.172	2.867	98.513						
5	0.085	1.419	99.932						
6	0.004	0.068	100.000						

On the first latent dimension, tests for assessing body weight and body circumference, and tests for assessing subcutaneous fat tissue, show high saturation: body weight (.926) body mass index (.956), abdominal circumference (.962), upper arm skinfold (.851) and back skinfold (.864). All applied tests for assessing morphological characteristics except the body height test (ATLVIS), have high projections and thus diagnostic validity on this latent dimension.

In the second latent dimension, the body height assessment test (.885) has a high projection, and thus diagnostic validity on this latent dimension.

Table 2. *Factor Loadings of Variables on Extracted Components (Component Matrix 1 and 2)*

Component Matrix[a]	Component	
	1	2
I_ATLVIS	0.421	0.885
I_ATLMAS	0.926	0.343
I_BMI	0.956	-.086)
I_AOBTRB	0.962	0.011
I_ANABNA	0.851	-.382)
I_ANABLE	0.864	-.339)

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

Table 3. *Factor analysis – Varimax rotated component matrix for the initial measurement*

Rotated Component Matrix[a]	Component	
	1	2
I_ATLVIS	0.026	0.979
I_ATLMAS	0.707	0.689
I_BMI	0.909	0.309
I_AOBTRB	0.875	0.400
I_ANABNA	0.933	-.004)
I_ANABLE	0.927	0.040

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

Factor analysis, applied to anthropometric measures with varimax rotation, identifies two independent factors that explain different aspects of body composition. This factor structure shows that anthropometric characteristics can be grouped into two main latent factors: one that reflects body mass and adipose tissue and another that represents basic body dimensions.

The first factor shows high projection with body mass index (BMI) (.909), waist circumference (.875), upper arm skinfold (.933) and back skinfold (.927). These strong correlations indicate that this factor mainly reflects variations in body mass and adipose tissue. The high projection of these variables indicates that the factor is mainly related to body composition, especially adiposity. Therefore, this factor can be interpreted as a factor of body mass and adipose tissue.

The second factor has an exceptionally high correlation with body height (.979), while body weight also has a significant projection (.689). This suggests that the factor mainly reflects basic body dimensions, i.e. body height as a dominant characteristic. Since body weight has a relatively high projection with both the first and second factors, it can be concluded that it is a complex variable, which is influenced by both adipose tissue and body structure. In view of this, the second factor can be defined as a factor of longitudinal dimensionality.

Table 4. *Factor Analysis Results -Total variance explained in the final measurement*

Component	Total	% of Variance	Cumulative %	Total	% of Varianc	Cumulative %	Total	% of Variance	Cumulative %
1	4.348	72.470	72.470	4.348	72.470	72.470	3.979	66.315	66.315
2	1.164	19.406	91.876	1.164	19.406	91.876	1.534	25.561	91.876
3	0.233	3.880	95.755						
4	0.154	2.570	98.325						
5	0.097	1.609	99.935						
6	0.004	0.065	100.000						

Based on the intercorrelation matrix of the applied manifest variables of morphological characteristics, characteristic roots (lambda) were obtained, which explain the common variance of each isolated principal component in the first-order space (table no. 4). The applied Guttman-Kaiser criterion extracted 2 significant latent dimensions. The first of them with an eigenvalue (total=3.979) explains 66.315% of the total variance of the variables, the second with a value (total=1.534) explains 25.561% of the total variance. The total explained variance by the extracted latent dimensions amounts to 91.876% of the common variance of the entire system and seems to be sufficient for the explanation of the variability and covariability of the manifest variables applied to the sample of students.

Table 5. *Factor loadings of variables on extracted components (Component Matrix 1 and 2)*

Component Matrix[a]	Component	
	1	2
second_ATLVIS	0.362	0.914
second _ATLMAS	0.926	0.339
second _BMI	0.956	-.092)
second _AOBTRB	0.958	0.003
second _ANABNA	0.856	-.343)
second _ANABLE	0.892	-.298)

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

From the heights of the projections of the manifest variables on the first principal component of the Varimax factor matrix, it can be concluded that most variables have significant, moderately high and high projections, which could mean that the obtained factors are in a relatively significant correlation. The value of the communalities is high, which means that the system of factors defines the variability and covariability of the manifest variables relatively well.

Table 6. *Factor analysis – Varimax rotated component matrix for the initial measurement*

Rotated Component Matrix[a]	Component	
	1	2
II_ATLVIS	0.029	0.983
II_ATLMAS	0.755	0.634
II_BMI	0.930	0.239
II_AOBTRB	0.900	0.329
II_ANABNA	0.922	-.031)
II_ANABLE	0.940	0.024

Legend: ATLVIS (Body height), ATLMAS (Body weight), BMI (Subcutaneous fat index), AOBTRB (Abdominal circumference), ANABNA (Upper arm skinfold), ANABLE (Back skinfold)

In the final measurement, factor analysis with varimax rotation again isolated two latent factors, reflecting the structure of the anthropometric measures. The first factor shows high correlations with body mass index (BMI) (.930), waist circumference (.900), upper arm skinfold (.922) and back skinfold (.940), indicating a clear latent dimension reflecting body mass and subcutaneous fat. This consistency with the results of the first measurement confirms that this factor can be interpreted as a body mass and adiposity factor, which includes the basic parameters of body composition related to adiposity. The high correlation of body weight (.755) with this factor further confirms that this factor mainly reflects the fat and muscle component of body structure, i.e. it can be defined as a body mass and adipose tissue factor.

The second factor is dominantly defined by body height (.983), while body weight has a moderate correlation (.634), indicating that this factor predominantly reflects constitutive body dimensions. Such a factor model suggests that the factor can be interpreted as a factor of longitudinal dimensionality, which is consistent with the results of the first measurement.

Discussion

The comparative analysis between the two measurements shows a high stability of the factor structure, with the factors maintaining a similar composition. This indicates a high replicability of the identified factors and confirms that anthropometric characteristics can be reduced to two main latent dimensions: ***body mass and adiposity and longitudinal dimensionality***. This factor stability may have important implications for monitoring body composition in sports and health contexts. Scepanović, T., & Protić-Gava, B. (2013), in their study on determining the factor structure of morphological status in male adolescents (15 years ± 6 months), isolated the same factors, which fully coincides with the analyses of this research. Also, according to Rađo, I., et al. (2011), in a study conducted on a sample of 1332 boys aged 11-14, isolate dimensions (volume factors, subcutaneous fat, growth and development, and longitudinal dimensionality) with which they identify and define the latent structures of morphological characteristics. Most of the previous research on determining the latent structure of morphological characteristics has been conducted on young athletes aged 11-15 (basketball players, swimmers), not only on students, but still the same latent dimensions have been extracted (Ostrowska, B., et al.2006 and Begu, B., al. 2018).

The analysis of morphological data from early adolescence (12–14 years) identified two dominant latent dimensions. The first factor, designated as the "transverse morphological dimension", is formed by the variables body weight, abdominal circumference, upper arm skinfold, back skinfold and body mass index (BMI). These indicators indicate that this factor reflects body mass and the amount of subcutaneous fat tissue. In other words, it is a dimension that expresses the volume and mass of the body, i.e. the physical "thickening" of the body, which is characteristic of this age due to hormonal changes associated with puberty.

The second factor represents the "longitudinal morphological dimension" and is mainly defined through body height. It reflects the longitudinal expansion of the body, i.e. growth in height, which is also a central process in pubertal development in adolescents.

Approximately equal shares of the variation were accounted for by these two factors, which were relatively stable within our sample. This means that the factor structure is maintained without significant changes by gender and other subgroups, indicating a gradual, consistent pattern of development in early adolescence (Gudelj et al., 2009). Namely, we can conclude that our results confirm the existence of two key scans in morphological change, one associated with the accumulation of tissue mass and generally proportional body growth, and the second with intensive prolonged bone expansion that overall explains a significant part of the variation in growing children.

From a scientific point of view, this two-dimensional structure reflects the complex nature of biological maturation in adolescents. The factor reflecting the longitudinal growth of the body, i.e. increase in body height, is associated with intensive growth in height and can be interpreted as an indicator of accelerated biological maturation. In some cases, this growth occurs earlier in girls than in boys, which is consistent with the general patterns of pubertal maturation. On the other hand, the transverse factor, which includes body weight, fat tissue and bulkiness, is more characteristic of boys at this age, in whom puberty usually begins later, and the phase of intensive growth in height has not yet fully begun. According to Gudelj et al. (2009), in 12-year-old girls the "full swing" of puberty is already present (intensive prolonged growth), while in boys this period is still expected to occur (delayed onset of puberty). These differences indicate that the morphological age of children can differ drastically from the chronological age, which is of crucial importance in the context of developmental morphology. Our data suggest that genetic and hormonal mechanisms play a dominant role in determining these developmental trajectories, while the influences of physical activity (quality and quantity of exercise) largely serve only as additional factors. This is in agreement with the conclusion of Gudelj et al. (2009) that the intensity of kinesiological activity only partially explains these morphological processes. In other words, this means that for the successful rationalization of physical activity and sports at this age we should be guided primarily by biological, and not only by chronological, maturation.

Our findings are largely consistent with a growing body of international research. For example, Gudelj et al. (2009) used a similar factorial distinction in their analysis of 12-year-olds from Croatia and observed two main morphological dimensions – one related to fat accumulation and muscle development, and the other to lower bone growth – illustrating the same bipolar pattern of development that we found. In line with this, Damsgaard et al. (2001) documented anthropometric differences in child athletes (9–13 years), noting that boys and girls, as well as different sports, select children with specific morphological profiles. They, for example, found no significant effect of training itself on body composition, suggesting that genetic characteristics dictate morphology in selective sport participation. Our data are consistent with this idea: physical activity per se does not obscure the underlying developmental trajectories detected by factor analysis.

Similarly, Katanić et al. (2023) in a representative study of adolescents in Montenegro highlight the interaction between environment and growth. They found that urban children aged 12–14 years had lower body mass index (BMI) values than rural children, while girls in the central areas of the country were taller than those in the northern and coastal regions. These findings are consistent with ours, as they suggest that structural factors, such as urban or rural environment, influence the body characteristics and health parameters of adolescents, which further confirms our results.

A broad perspective on the global problem is provided by studies on the epidemiology of obesity. Wang & Lobstein (2006) reported that the prevalence of childhood overweight has increased in almost all countries in recent decades, especially in economically developed societies. The World Health Organization (WHO) also warns of an explosion of obesity in adolescents: according to WHO statistics, the percentage of youth who are overweight or obese has increased from about 4% in 1975 to over 18% in 2016, with nearly 340 million children and adolescents aged 5–19 years classified as overweight or obese. Ogden et al. (2016) further reported that in the United States in 2015–2016, nearly 18.5% of the population aged 2–19 years was obese. These global trends confirm the importance of our findings and illustrate the urgency of continuing to monitor physical growth and body composition in the early teens.

Among the strengths of this study is the use of consistent and quite extensive anthropometric measurements. By collecting a wide set of over twenty morphological variables and their multivariate modeling (factor analysis), we ensured qualitative and quantitative-structural processing of the data. The use of factor analysis reduces the complexity of the input measures and highlights their internal structure, which facilitates scientific interpretation. In addition, the sample was large enough to ensure statistical robustness, and all measures were performed according to standardized protocols with high reliability. With these methodological approaches, the study obtains the necessary representativeness and validity, which ensures the precision of the findings.

However, it is necessary to highlight certain limitations of the research. First of all, hormonal or genetic indicators of biological maturity were not included, which is why we cannot directly analyze the internal mechanisms that drive morphological development in the subjects. A limited geographical area was covered, so the results are initially valid for this context, while their application to wider populations needs to be confirmed by further studies. Factor analysis as a research method carries its own limitations and confirmatory analysis of an independent set is needed to supplement the reliability of the factor structure. Also, there may be variables that were not included (e.g. daily eating habits, pharmaceutical influences or mental health) that affect growth, and which our study did not cover. These factors should be taken into account when interpreting the results.

The identification of stable latent dimensions in morphological development in adolescents allows for more informed adjustment of physical activities and sports programs in schools. Instead of being guided solely by chronological age, teachers and trainers should consider biological maturity as reflected in morphological indicators. The presence of different factor profiles – such as height growth or increased body mass – requires an individualized approach to load dosing, exercise selection, and progress monitoring. Such an approach may contribute to better growth support, injury prevention, and early recognition of developmental abnormalities. Future research should focus on monitoring the stability and variability of the identified latent dimensions over a longer period of time. Longitudinal studies with multiple measurement points would allow for the distinction between the effects of age, training, and biological maturation on morphological structure (Malina & Bouchard, 2004). Additionally, the inclusion of biological indicators, such as hormonal parameters or skeletal maturity, would allow for a deeper understanding of the physiological mechanisms behind each factor. To verify the resulting structure, applying confirmatory factor analysis on independent samples is a logical next step.

CONCLUSION

The conducted factor analysis of morphological characteristics in male students from the upper grades of primary education, allowed the identification of two clearly differentiated and stable latent dimensions. The first covers body mass and subcutaneous fat tissue, while the second refers to the longitudinal structure, i.e. growth in height. The comparison between the initial and final measurements showed high consistency in the composition of the factors, which indicates the stability of the structure over time. This stability confirms the relevance of the obtained factor organization and opens up possibilities for its application in monitoring and assessing morphological development in educational and sports contexts. The research indicates that the appropriate selection of anthropometric indicators allows for the identification of the essential components of body structure in adolescents with a small group of variables.

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