THE INVESTIGATION OF MORPHOLOGY DIFFERENCES IN PUBERTY PERIOD

Utvić Nikola, Mojsilović Zoran, Stanić Đorđe, Arsenijević Radenko
Faculty of sport and physical education, University of Prishtina, Leposavić, Serbia

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Abstract: *The objective of this study was to investigate the differences in morphological factors, between different ages in puberty period (10, 11, 12, 13, and 14 year old paticipants), and for both sexes independently. The sample consisted of 132 boys (body height: 157.32 ± 10.57 cm, body mass: 51.18 ± 14.92 kg, body mass index: 20.36 ± 4.26 kg/m²) and 194 girls (body height: 155.74 ± 10.15 cm, body mass: 48.81 ± 14.52 kg, body mass index: 19.76 ± 4.17 kg/m²). Anthropometric and body composition variables encompassed body height (BH), body mass (BM), body mass index (BMI), total body water (TBW), proteins (PRT), minerals (MIN), body fat mass (BFM), free-fat mass (FFM), sceletal muscle mass (SMM), and visceral fat (VIS). For variables measurement InBody bioelectrical impedance analysis was used. To investigate differences between age groups, one-way ANOVA was used, independently for both sexes. Statistical significance was establised in BH (p = 0.000), BM (p = 0.000), TBW (p = 0.000), PRT (p = 0.000), MIN (p = 0.000), FFM (p = 0.000), and SMM (p = 0.000), for boys, and in BH (p = 0.000), BM (p = 0.000), BMI (p = 0.000), TBW (p = 0.000), PRT (p = 0.000), MIN (p = 0.000), BFM (p = 0.000), FFM (p = 0.000), SMM (p = 0.000), and VIS (p = 0.002). The present findings suggest that turbulent development in puberty period is displaying many differences in analyzed morphological variables.*
Key words*: body fat mass, sceletal muscle mass, total body watter, free-fat mass*

INTRODUCTION

Puberty represents a pivotal period marked by rapid physical and morphological changes, where adolescents experience significant shifts in body composition, height, weight, and body fat distribution (Satterthwaite et al., 2014; Sun et al., 2024). These physiological changes are driven by hormonal processes unique to puberty, such as increased levels of testosterone in boys and estrogen in girls, leading to distinctive growth patterns between sexes (Ortega et al., 2021). The variability in these developmental trajectories underscores the importance of studying morphological changes to better understand adolescent health, fitness, and long-term outcomes (Medeiros et al., 2014; Feibelmann et al., 2015).

During adolescence, the body undergoes dynamic structural and functional transformations, affecting not only physical appearance but also physical capacities, metabolic rate, and mental health (Stang & Story, 2005; Nti et al., 2024). For example, research has shown that increases in muscle mass and bone density are more prominent in boys, while girls tend to experience a higher accumulation of body fat due to hormonal differences (Genc et al., 2018; Widyanti et al., 2015). These changes necessitate age- and sex-specific interventions in physical activity and nutrition programs to promote optimal health outcomes and support the unique needs of adolescents at different stages of growth (Sarafyniuk et al., 2021).

Analyzing these morphological variations is essential for developing targeted health interventions and fitness programs tailored to adolescents. Such personalized approaches not only help in promoting physical fitness but also address the specific physiological demands of puberty, reducing the risk of conditions such as obesity, cardiovascular disease, and osteoporosis later in life (Lee et al., 2019; Schoppen et al., 2010). A clear understanding of these body composition changes allows healthcare providers to create guidelines that cater to diverse health needs, supporting immediate developmental goals while laying a foundation for long-term wellness (Nikšić et al., 2021; Utvić et al., 2022).

The psychological impact of these changes is also considerable. Adolescents are particularly susceptible to body image issues as they become more self-conscious of their appearance, especially given the influences of social media and peer comparison (Wu et al., 2024). Research suggests that the physical changes in puberty can impact self-esteem, mental health, and social interactions, which can lead to emotional stress or, in some cases, disorders like anxiety and depression (Ortega et al., 2021;

Utvić et al., 2022). Addressing the rapid growth in puberty also requires awareness of potential health risks, such as musculoskeletal injuries from intense physical activities and psychological stress from body changes (Wu et al., 2024). Boys, for instance, are at a higher risk of injuries related to muscle overuse, while girls may face challenges related to body image and self-esteem as body fat distribution changes (Ortega et al., 2021). By recognizing these risks, tailored interventions can include safe training practices, balanced nutrition, and mental health support to help adolescents manage these challenges in a healthy way. The aim of this study was to investigate the differences in morphological factors, between different ages in puberty period (10, 11, 12, 13, and 14 year old participants), and for both sexes independently.

METHOD

Study Design

This cross-sectional study aimed to investigate morphological differences in adolescents during puberty by analyzing body composition, height, weight, and BMI, enabling comparisons between boys and girls at similar developmental stages.

Sample

The sample included 326 adolescents representing typical morphological characteristics during puberty:

- Boys (n = 132): Average height 157.32 ± 10.57 cm, weight 51.18 ± 14.92 kg, BMI 20.36 ± 4.26 kg/m^2.
- Girls (n = 194): Average height 155.74 ± 10.15 cm, weight 48.81 ± 14.52 kg, BMI 19.76 ± 4.17 kg/m^2.

Participants were recruited from local schools, with parental consent. Inclusion criteria included ages 12-16, free from chronic health conditions impacting development.

Data Collection Procedures

Data collection involved a single session per participant, including:

1. Body Height: Measured to the nearest 0.1 cm with a stadiometer.
2. Body Mass: Measured to the nearest 0.1 kg on a digital scale, with light clothing and no shoes.
3. Body Composition: Assessed with the InBody 270, which uses bioelectrical impedance analysis (BIA) for accurate body fat, muscle mass, total body water, and segmental distribution readings. Each analysis took about one minute.
4. BMI: Calculated using BMI = weight (kg) / height $(m)^2$.

Statistical Analysis

Descriptive statistics (mean, standard deviation, minimum, maximum, and CV%) were calculated for all parameters. One-way ANOVA was used to assess age differences within the puberty period and for each sex independently.

RESULTS

The one-way ANOVA analyses for boys and girls revealed significant differences in various body composition and morphological variables across age groups during puberty, underscoring the unique developmental patterns in each gender.

Table 1 Results of one-way ANOVA for boys

	Sum of Squares	df	Mean Square	F	Sig.
BH (cm)	7354.101	4	1838.525	32.011	**.000**
BM (kg)	7316.472	4	1829.118	10.633	**.000**
BMI (kg/m2)	170.488	4	42.622	2.447	.050
TBW (l)	3136.405	4	784.101	34.940	**.000**
PRT (kg)	227.146	4	56.787	33.981	**.000**
MIN (kg)	29.116	4	7.279	30.995	**.000**
BFM (kg)	350.938	4	87.734	1.344	.257
FFM (kg	5848.681	4	1462.170	34.602	**.000**
SMM (kg)	2067.891	4	516.973	34.323	**.000**
VIS (n)	71.692	4	17.923	1.161	.331

BH - body heigth, BM - body mass, BMI - body mass index, TBW - total body water, PRT - proteins, MIN - minerals, BFM - body fat mass, FFM - free-fat mass, SMM - sceletal muscle mass, VIS - visceral fat

The results indicate statistically significant differences in several growth and muscle mass variables: body height (BH), body mass (BM), total body water (TBW), protein content (PRT), mineral content (MIN), fat-free mass (FFM), and skeletal muscle mass (SMM), all with p-values less than .001. This highlights the emphasis on lean mass development in male adolescents. Additionally, body mass index (BMI) displayed significance at the .05 level, reflecting some variability in body composition changes related to height and weight increases during puberty. Conversely, body fat mass (BFM) and visceral fat (VIS) did not exhibit significant differences, which suggests that fat accumulation patterns may remain relatively stable in boys during this developmental phase, with muscle growth being the primary focus.

Table 2 Results of one-way ANOVA for girls

	Sum of Squares	df	Mean Square	F	Sig.
BH (cm)	7680.552	4	1920.138	29.757	**.000**
BM (kg)	11605.493	4	2901.373	18.844	**.000**
BMI (kg/m2)	495.360	4	123.840	8.200	**.000**
TBW (l)	2975.099	4	743.775	32.385	**.000**
PRT (kg)	220.601	4	55.150	32.643	**.000**
MIN (kg)	31.717	4	7.929	34.437	**.000**
BFM (kg)	1238.071	4	309.518	6.131	**.000**
FFM (kg	5621.630	4	1405.408	32.668	**.000**
SMM (kg)	1990.092	4	497.523	32.512	**.000**
VIS (n)	238.169	4	59.542	4.414	**.002**

In girls, the ANOVA results indicate statistically significant differences across all analyzed variables, including body height (BH), body mass (BM), body mass index (BMI), total body water (TBW), protein content (PRT), mineral content (MIN), body fat mass (BFM), fat-free mass (FFM), skeletal muscle mass (SMM), and visceral fat (VIS), with p-values generally below .001. These findings suggest substantial changes in both muscle and fat-related variables during puberty, potentially due to the influence of estrogen on fat distribution and overall body composition. The significance observed in visceral fat ($p = .002$) indicates more variability in fat accumulation among females during adolescence.

In summary, the analysis highlights distinct developmental trajectories in body composition for boys and girls. Boys experience more pronounced changes in lean muscle and skeletal mass, while girls display significant changes across both fat and muscle-related metrics. These findings underscore the need for gender-specific approaches in health and fitness programs to address the developmental differences in adolescents.

DISCUSSION

The results for both boys and girls indicate significant differences in growth and body composition metrics, with distinct patterns between the sexes. Boys show more variation in muscle and lean mass-related variables (e.g., fat-free mass (FFM), skeletal muscle mass (SMM), protein content), while girls demonstrate significant differences across both fat and muscle-related metrics, with noticeable variation in body fat mass (BFM) and visceral fat (VIS). These findings align with previous research, highlighting the influence of testosterone in boys, which promotes muscle growth, and estrogen in girls, which affects fat distribution (Ortega et al., 2021; Satterthwaite et al., 2014). This suggests that muscle development is a primary focus of growth in male adolescents, while fat accumulation is more prominent in females due to hormonal influences (Genc et al., 2018; Sun et al., 2024).

These results underscore the importance of considering gender-specific physiological changes during puberty, as boys and girls experience different patterns of body composition changes. Understanding these differences is crucial for developing tailored health and fitness programs that meet the specific needs of adolescents based on gender and stage of pubertal development (Feibelmann et al., 2015; Nikšić et al., 2021).

Our findings reveal that boys and girls follow different growth trajectories, with boys generally displaying higher muscle-related measurements, while girls tend to have a greater body fat percentage. These differences are attributed to hormonal influences, particularly testosterone in boys and estrogen in girls, which contribute to muscle growth and fat accumulation, respectively (Ortega et al., 2021). The observed differences in body height, body mass, and total body water between boys and girls reflect these divergent developmental patterns (Stang & Story, 2005).

Boys in this study showed significant variability in muscle mass metrics, including skeletal muscle mass (SMM) and fat-free mass (FFM), aligning with findings by Medeiros et al. (2014), who observed that male adolescents tend to gain more muscle mass due to the anabolic effects of testosterone. In contrast, girls showed significant differences in both muscle- and fat-related measurements, including body fat mass (BFM) and visceral fat (VIS), likely influenced by estrogen. This suggests a higher risk of fat accumulation in girls during adolescence, which could impact metabolic health if not managed with proper nutrition and physical activity (Schoppen et al., 2010; Nti et al., 2024).

The differences in FFM and SMM among boys suggest they develop more lean muscle mass, which contributes to a faster metabolism and greater calorie expenditure. This finding supports incorporating resistance training into physical activity programs for boys to enhance muscle mass and support healthy body composition (Utvić et al., 2022). For girls, the variability in body fat mass and visceral fat highlights the need for balanced aerobic and strength training exercises to maintain a healthy fat-to-muscle ratio, which is critical in reducing the risk of metabolic syndrome and cardiovascular disease later in life (Sarafyniuk et al., 2021; Wu et al., 2024).

Total body water (TBW) and protein mass (PRT) were significantly different for both boys and girls, indicating differences in hydration levels and muscle content. Boys displayed higher levels of TBW and PRT, which aligns with their increased muscle mass, as muscle tissue retains more water than fat (Feibelmann et al., 2015). Adequate hydration and protein intake are essential for supporting these physiological changes and promoting muscle recovery and growth (Nikšić et al., 2021).

In girls, differences in TBW and PRT may reflect variability in hydration and muscle mass influenced by diet and activity levels. Providing guidance on adequate hydration and balanced protein intake may support muscle maintenance while mitigating fat accumulation (Ortega et al., 2021).

BMI showed marginal significance for boys ($p = .050$) and was highly significant for girls ($p < .001$). While BMI is a common metric for assessing body composition, it does not differentiate between fat and muscle, limiting its accuracy in evaluating adolescent health. For instance, a high BMI in boys may result from increased muscle mass, while in girls, it may not fully capture fat distribution, particularly visceral fat (Widyanti et al., 2015). These findings suggest that more detailed body composition assessments are recommended to accurately gauge adolescent health beyond BMI alone (Lee et al., 2019).

The distinct body composition changes observed underscore the need for gender-specific health and fitness programs. Boys may benefit from strength training and higher protein intake to support muscle

growth, while girls should focus on a balanced exercise regimen that includes both aerobic and resistance exercises to maintain muscle and manage fat accumulation (Genc et al., 2018). Educating adolescents on balanced nutrition and exercise tailored to their developmental needs can foster healthy habits and reduce the risk of future health issues related to body composition (Ortega et al., 2021; Stang & Story, 2005).

Limitations and future research directions

This study's cross-sectional design restricts our ability to track changes over time, and a longitudinal approach would provide more comprehensive insights into body composition development across puberty (Medeiros et al., 2014). While the InBody 270 device offers reliable measurements, hydration status can influence results. Future studies should consider multiple assessment methods, such as DXA, to enhance accuracy (Nikšić et al., 2021). Expanding the sample size and age range could improve the findings' generalizability and contribute to broader insights into adolescent body composition (Utvić et al., 2022).

CONCLUSION

This study highlights notable differences in morphological variables during puberty for both boys and girls, reflecting significant physical changes that occur throughout this developmental period. Among the boys, significant differences were observed in body height (BH), body mass (BM), total body water (TBW), protein content (PRT), minerals (MIN), fat-free mass (FFM), and skeletal muscle mass (SMM). For the girls, differences were confirmed across all analyzed variables, including body height (BH), body mass (BM), body mass index (BMI), total body water (TBW), protein content (PRT), minerals (MIN), body fat mass (BFM), fat-free mass (FFM), skeletal muscle mass (SMM), and visceral fat (VIS).

These findings suggest that the pubertal period is marked by turbulent development, with each sex following distinct morphological changes. The differences observed underscore the importance of considering gender-specific factors when assessing adolescent growth patterns and body composition.

One limitation of this study is the lack of fitness-related measurements, which could provide valuable insights into the relationship between physical fitness and morphological development across different stages of puberty. This omission suggests that while significant physical changes have been documented, the interaction between morphological changes and fitness levels remains unexplored. Addressing this gap in future research would enhance our understanding of adolescent development, providing a more comprehensive perspective on the impact of puberty on physical and fitness outcomes.

Overall, the study underscores the dynamic nature of physical development during puberty, with substantial variability in key morphological metrics. These findings could inform age- and sex-specific health and fitness programs tailored to the unique developmental needs of adolescents, ultimately promoting healthier growth patterns and long-term well-being.

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ИСТРАЖИВАЊЕ РАЗЛИКА У МОРФОЛОГИЈИ У ПЕРИОДУ ПУБЕРТЕТА

Utvić Nikola, Mojsilović Zoran, Stanić Đorđe, Arsenijević Radenko

Сажетак: *Циљ овог истраживања био је да се испитају разлике у морфолошким факторима, између различитих узраста у периоду пубертета (10, 11, 12, 13 и 14 година стари испитаници) и за оба пола независно. Узорак су чинила 132 дечака (телесна висина: 157,32 ± 10,57 цм, телесна маса: 51,18 ± 14,92 кг, индекс телесне масе: 20,36 ± 4,26 кг/м2) и 194 девојчице (телесна висина: 155,74 ± 14,5 цм, 80. ± 14,52 кг, индекс телесне масе: 19,76 ± 4,17 кг/м2). Антропометријске варијабле и варијабле телесне композиције обухватале су: телесну висину (BH), телесну масу (BM), индекс телесне масе (BMI), укупне телесне течности (TBW), протеине (PRT), минерале (MIN), телесну масу масти (BFM), без-масну масу (FFM), масу скелетних мишића (SMM) и висцералне масти (VIS). За мерење варијабли коришћена је ИнБоди анализа биоелектричне импедансе. Да би се истражиле разлике између старосних група, коришћена је једносмерна ANOVA, независно за оба пола. Статистичка значајност је утврђена је вариаблама у BH (p = 0.000), BM (p = 0.000), TBW (p = 0.000), PRT (p = 0.000), MIN (p = 0.000), FFM (p = 0.000) и SMM (p = 0.000), за дечаке, и у BH (p = 0.000), BM (p = 0.000), BMI (p = 0.000), TBW (p = 0.000), PRT (p = 0.000), MIN (p = 0.000), BFM (p = 0.000), FFM (p = 0.000), SMM (p = .,000) и VIS (p = 0.002). Садашњи налази сугеришу да турбулентни развој у пубертету показује многе разлике у анализираним морфолошким варијаблама.*

Кључне речи: *телесна маса масти, маса скелетних мишића, укупне телесне течности, без-масна маса*