INVESTIGATING CHILD LINEAR GROWTH: AN EXPLORATION OF ANTHROPOMETRIC CHARACTERISTICS AMONG CHILDREN AGES 6 TO 14 IN THAI NGUYEN CITY, VIETNAM

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Abstract: Comprehending the anthropometric characteristics of children serves as the foundational framework for devising efficacious public health interventions and formulating policies aimed at fostering holistic well-being. This research aimed to assess anthropometric characteristics, including height, weight, and body mass index (BMI), to evaluate the linear growth of 6 to 14-year-old children in Thai Nguyen city. A cross-sectional study involving 1,861 students from 915 Giang Sang Primary and Secondary School and Hoang Van Thu Secondary School revealed robust positive correlations between height and weight ($r = 0.803$) and between weight and BMI ($r = 0.819$). The height and BMI correlation was positive but moderate ($r = 0.345$). Over the 6 to 14 age range, boys experienced a weight increase of 32.4 kg (from 24.5 kg to 56.9 kg), and girls increased by 28.7 kg (from 21.7 kg to 50.4 kg). Height gain for boys was 46.3 cm (from 120.8 cm to 167.1 cm), while girls increased by 36 cm (from 118.8 cm to 154.8 cm). The BMI of boys rose by 3.7 kg/m² (from 16.7 kg/m² to 20.4 kg/m²), and girls increased by 6.0 kg/m² (from 15.3 kg/m² to 21.3 kg/m²). BMI for age z-score showed age-related fluctuations. The variability in these anthropometric indicators differed significantly between boys and girls. Therefore, the growth of certain anthropometric characteristics in 6 to 14-year-old children in Thai Nguyen city demonstrate linear positive outcomes. Finally, it is important to consistently monitor the growth of children, aligning with global child growth charts.

Keywords: Linear growth, anthropometric characteristics, 6-14-year-old children, Thai Nguyen city.

1. INTRODUCTION

In recent years, understanding the anthropometric characteristics of children has become increasingly imperative for designing effective public health interventions and shaping policies to promote overall well-being. Among the various factors influencing a child's growth and development, anthropometry serves as a fundamental tool to assess nutritional status, monitor health trends, and identify potential areas for intervention. The investigation of anthropometric characteristics emerges as a highly reliable methodology for comprehensively delineating the human physique and monitoring the progression of physical growth across various age groups. This approach not only enables the identification of normative developmental milestones at specific ages but also contributes

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to the prognostication of future health risks that may manifest in later stages of life, including orthopedic deformities, overweight, obesity, and undernutrition-related ailments (Goh et al., 2014; Piqueras et al., 2021). Furthermore, delving into anthropometric characteristics during the formative years of childhood and adolescence reveals additional dimensions. During this developmental stage, individuals frequently exhibit a limited comprehension of the inherent alterations in the body's maturation processes. Consequently, amid psychological, behavioral, and social transformations, this phase may instigate a manifestation of discontent regarding one's body shape. This dissatisfaction can manifest in the adoption of diverse unhealthy behaviors, thereby posing a potential threat to the progression of normal growth during this crucial period, consequently precipitating health complications (Saleh, 2020).

Due to its cost-effectiveness, simplicity of implementation, and non-invasive nature, the utilization of anthropometric screening has gained substantial popularity for assessing the risk of metabolic syndrome in children and adolescents (Griffiths et al., 2013). Scientific investigations have elucidated that various aspects of health and weight status exhibit considerable variability contingent on socioeconomic status and geographic region (Aberle et al., 2009). Consequently, acquiring epidemiological data specific to each country, each region pertaining to the prevalence of anthropometric traits, body composition, and components of health-related fitness among children and adolescents assumes paramount importance. These data serve as indispensable foundations for formulating effective public health strategies and devising appropriate interventions to promote physical activity (Birnie et al., 2011; Veiga et al., 2023).

Numerous research endeavors have probed into the disparities in anthropometric measures and weight status among adolescents across diverse countries and regions (Choudhary et al., 2016; Katanic et al., 2023; Sofi et al., 2021). In Vietnam, the investigation of anthropometric indicators in a cohort of 2,334 children enrolled in eight primary schools situated in rural areas of Hai Phong city, serves as the foundational framework for discerning the prevalence rates of underweight, stunting, wasting, and anthropometric failure among the studied pediatric population (Hoang et al., 2018).

This research delves into the anthropometric characteristics, specifically targeting the investigation of child linear growth among 6-15-year-old children in Thai Nguyen city, Vietnam, in the year 2023. Located in the northern part of Vietnam, Thai Nguyen city stands as a microcosm of the diverse socio-cultural landscape within the country. Factors such as regional dietary practices, lifestyle, and socioeconomic status contribute to the unique anthropometric profiles observed among children in this specific locale. These factors, coupled with the rapidly evolving societal landscape, underscore the need for a contemporary examination of child linear growth patterns. Anthropometric characteristics serve as invaluable indicators, offering a lens through which we can decipher the multifaceted interplay of genetics, nutrition, and socio-economic factors on the growth trajectories of the younger generation.

This study was conducted to evaluate anthropometric characteristics, thereby assessing the linear growth of children 6-14 years old in Thai Nguyen city. These
indicators play an important role in evaluating nutritional adequacy and identifying potential areas for targeted health interventions. The knowledge derived from this study is poised to contribute to the formulation of targeted strategies and interventions that address the unique needs of this demographic, fostering a healthier and more resilient future for the children of Thai Nguyen city.

2. SUBJECTS AND METHODS

2.1. Participants

The study sample comprises children and early adolescents aged 6-14, drawn from both primary and secondary schools in Thai Nguyen city. A total of 1,861 students were part of this cross-sectional investigation. The recruitment of participants was voluntary, and the research procedures strictly adhered to ethical principles. The study was conducted at two selected schools in Thai Nguyen city, namely 915 Giang Sang Primary and Secondary School, and Hoang Van Thu Secondary School, employing the convenience sampling method for school selection.

2.2. Anthropometric Measurements

The standardized guidelines of the National Institute of Nutrition was employed to ascertain anthropometric characteristics. Anthropometric features were evaluated using the variables of body weight, body height, and BMI.

Children, attired in lightweight clothing and without shoes, underwent weight measurement using calibrated electronic body scales (TANITA, Japan). Each child's weight was recorded twice to the nearest 0.1 kg, and in cases where the two measurements differed by more than 0.1 kg, a third measurement was conducted.

Height measurements, taken twice to the nearest 0.1 cm using a stadiometer, were carried out with children devoid of hair ornaments, braids, hats, shoes, or socks. If the duplicate height measurements exhibited a difference exceeding 0.1 cm, a third measurement was undertaken.

The final weight and height values were computed as the mean of the two or three measurements for each child, as appropriate. All anthropometric measurements adhered to standardized procedures and were performed by trained school medical staff.

In this study, growth charts sourced from the World Health Organization (WHO), offering BMI percentiles tailored to the age and sex of children, were employed. The Z-score was computed using the subsequent formula:

\[ \text{BMI for age } z\text{-score} = \frac{\text{Child's BMI percentile} - \text{Mean BMI percentile for same age and sex}}{\text{Standard deviation of BMI percentile for same age and sex}} \]

BMI for age \( z\)-score close to 0 indicates that the child's BMI is close to the mean for their age and sex. A negative \( Z\)-score suggests that the child's BMI is below the mean. A positive \( Z\)-score suggests that the child's BMI is above the mean.
2.3. Statistical analysis

The statistical analyses were conducted using the SPSS16.0 statistical software package and R version 4.3.2. For normally distributed variables, the statistical tests encompassed the use of the Student's t-test for comparing means between two independent groups and the One-way ANOVA for comparing means among three or more independent groups. On the other hand, for non-normally distributed variables, common statistical tests included the Mann-Whitney U test for comparing medians between two independent groups and the Kruskal-Wallis test for comparing medians among three or more independent groups. The Chi-square test was applied for comparing two or more qualitative variables. Significance was established at P-values < 0.05.

3. RESULTS AND DISCUSSION

3.1. Correlation coefficient between anthropometric indicators

The correlation coefficient between height, weight, and BMI was shown in Figure 1. A robust positive correlation was evident between height and weight \((r = 0.803)\) as well as between weight and BMI \((r = 0.819)\). Meanwhile, the correlation between height and BMI was positive but of a moderate magnitude \((r = 0.345)\). These correlation coefficients provided insights into the relationships between height, weight, and BMI in the studied population, aiding in understanding the interplay of these variables.

The Pearson correlation coefficient between height and weight, weight and BMI, and height and BMI serves as a valuable indicator for assessing children's development and overall growth patterns. This coefficient quantifies the strength and direction of the linear relationship between these two anthropometric measures. Similar to our study, a research on 5,613 children within the age range of 6 to 12 years in Slovenia showed that the correlation coefficients between height and weight were determined to be 0.795 for boys and 0.805 for girls. Moreover, the correlation coefficients between weight and BMI exhibited values of 0.862 in boys and 0.866 in girls. Concurrently, the correlation coefficients relating height and BMI manifested as 0.418 in boys and 0.337 in girls (Planinšec & Fošnarič, 2009).

![Figure 1. Correlation coefficient between anthropometric indicators](image)

\(r\): Pearson correlation coefficient; *\(P < 0.05\); **\(P < 0.001\)
3.2. Linear growth in weight among students in Thai Nguyen

The students' weight was shown in Figure 2. The research findings in Figure 2 indicated that students' weight increases with age and the weight of boys was consistently higher than that of girls at most ages ($P < 0.05$), it suggests a gender-related difference in weight patterns. From 6 to 14 years old, boys increased 32.4 kg (from 24.5 kg to 56.9 kg), girls increased 28.7 kg (from 21.7 kg to 50.4 kg). At the age of 14, the average weight of boys was 56.9 kg, 6.5 kg higher than that of girls ($P = 0.009$).

The weight of students in this study was significantly higher than that of 11-14 year old students at Phung Thuong Secondary School, Hanoi, 2018. Accordingly, the weight of 14-year-old students at Phung Thuong Secondary School was 45.8 kg for boys and 46.7 kg for girls (Nguyen et al., 2019). As we all know, the average weight of 14-year-old students can vary on various factors such as genetics, nutrition, lifestyle, and overall health. However, through this data, it can be shown that the weight of students in Thai Nguyen recently tends to be higher than in previous years and in other localities. Information extracted from the 2001 Millennium Cohort Study (2001 MCS), encompassing a cohort of 18,818 individuals born between September 2000 and January 2002 residing in England, Scotland, Wales, or Northern Ireland, indicated that the weight of boys at the age of 11 was recorded as 40.9 kg, escalating to 58.6 kg at the age of 14. Conversely, in girls, the weight at age 11 was documented as 42.2 kg, ascending to 57.1 kg at age 14. This revealed an increment of 17.7 kg in boys and 14.9 kg in girls over the specified time period (Johnson et al., 2020). In our study, the weight gain of students was lower during the corresponding period, male children increased by 11 kg while female children increased by 8.1 kg.

Figure 2. Linear growth in weight among students in Thai Nguyen

* $P$-values obtained by Student's t-test. * $P < 0.05$; NS: Non-Significant

3.3. Linear growth in height among students in Thai Nguyen

The change in height by age among schoolchildren in Thai Nguyen city was shown in Figure 3. The height of students in Thai Nguyen had almost no gender difference between the ages of 6-11. Between the ages of 6 and 14, boys experienced a height gain of 46.3 cm, from 120.8 cm to 167.1 cm. Similarly, girls' height increased by 36 cm, from 118.8 cm to 154.8 cm. At the age of 12, there started to be a height difference, with boys likely being taller than girls. This difference continued to increase with age. By the age of 14, the average height of boys in Thai Nguyen was approximately 167.1 cm, while the average height of girls was around 154.8 cm. It's interesting to observe that the gender difference
in height becomes more prominent during adolescence, which is a common pattern seen in many populations around the world. During this period, boys tend to experience a growth spurt and reach their adult height faster than girls.

**Figure 3. Linear growth in height among students in Thai Nguyen**

In a specific study comparing the height of 14-year-old students, it was found that the height of students in this study was slightly higher than that of students of the same age in Bac Ninh in 2007 (153 cm in boys and 151 cm in girls) (Nguyen, 2007) and students in Indonesia in 2008 (151.4 cm in boys and 149.1 cm in girls) (Aman et al., 2018). When compared with other populations in the world, the height of students in Thai Nguyen is still low. The average height of 14-year-old boys in the United States was approximately 169 cm, and for girls, it was 161.8 cm (Fryar et al., 2021).

### 3.4. Linear growth in BMI among students in Thai Nguyen

The change in BMI by age and sex is shown in Figure 4. Between the ages of 6 and 14, the BMI of boys rose by 3.7 kg/m², from 16.7 kg/m² to 20.4 kg/m². In a parallel trend, girls' BMI increased by 6.0 kg/m², from 15.3 kg/m² to 21.3 kg/m². It appears that among 6 to 10-year-old students, boys had a higher average BMI compared to girls. However, from the ages of 11 to 14, no significant difference in BMI by sex was detected. This result may reflect the natural variations in growth and development during childhood and adolescence. As children enter puberty, there can be changes in body composition and fat distribution that can impact BMI.

**Figure 4. Linear growth in BMI among students in Thai Nguyen**

*P*-values obtained by Student's t-test. * *P* < 0.05; NS: Non-Significant
The information from a meta-analysis (from 1,099 sources included data on 24.1 million participants aged 5-17 years) regarding the global trends in children's and adolescents' BMI from 1975 to 2016. The data indicates that during this time period, there was a significant increase in the age-standardized mean BMI globally and in most regions. Based on the meta-analysis, on average, the BMI of children and adolescents increased by 0.32 kg/m² per decade for girls and 0.40 kg/m² per decade for boys over the studied period. The result of these increases in BMI was that in 2016, the age-standardized mean BMI for girls was 18.6 kg/m² (18.4-18.7 kg/m²), and for boys, it was 18.5 kg/m² (18.3-18.7 kg/m²). These results indicated that by 2016, the average BMI for both girls and boys had become virtually identical (Abarca-Gómez et al., 2017).

### 3.3. BMI for age z-score among students in Thai Nguyen

The BMI for age z-score serves as a quantifiable representation of the deviation of a specific BMI percentile from the average within a given cohort. The Z-score for BMI (Body Mass Index) with respect to age and sex is commonly used in pediatric populations to assess whether a child's BMI is within a normal range for their age and sex. The results showed that BMI for age z-score in boys was often higher than in girls. This value fluctuated with age and did not follow a linear change. In boys, notably, at the age of 11, the z-score was 0, suggesting that, on average, boys of this age had a BMI close to the median for their age. There was a decrease in z-score at the age of 11, indicating a lower BMI compared to the median. In girls, at the age of 11, there was a notable decrease with a z-score of -0.59, suggesting that, on average, girls of this age had a BMI below the median. Z-scores increased again at the age of 12, indicating a higher BMI compared to the median.

![Figure 5. BMI for age z-score among students in Thai Nguyen](image)

The data obtained from the Chinese National Survey on Students' Constitution and Health (CNSSCH) in 1985 (n = 14,683), 1995 (n = 7198), 2005 (n = 10,253) and 2014 (n = 18,521), encompassing children and adolescents aged 7-18 years in Xinjiang, revealed noteworthy trends. Specifically, the BMI-for-age z-score distribution exhibited an escalating mean BMI-for-age z-score over the 30-year period. Furthermore, a widening sex-based disparity in BMI-for-age z-scores was observed. In the year 2014, the BMI-for-age z-scores for ages 7 to 14 among boys were as follows: 0.47, 0.62, 0.70, 0.63, 0.64, 0.54, 0.35, 0.15, -0.07. Correspondingly, for girls, the BMI-for-age z-scores were: 0.18,
0.11, 0.06, -0.02, 0.15, 0.09, 0.09, 0.05 (Zhang et al., 2020). This data underscores the importance of assessing BMI-for-age z-scores in children and adolescents, aiming to identify individuals at high risk of obesity-related diseases. Implementing appropriate preventive measures is crucial in mitigating the potential health risks associated with obesity in this population.

This study has several strengths. The study includes children aged 6 to 14 years, providing a broad understanding of linear growth patterns during a crucial period of development. Focusing on children in Thai Nguyen city, Vietnam, ensures that the findings are contextually relevant and applicable to the local population. The use of anthropometric characteristics allows for direct assessments of linear growth, providing valuable insights into nutritional status and overall health. However, some weaknesses still exist. Since the study focuses on children from Thai Nguyen city, the findings may not be generalizable to children in other regions or countries with different socio-economic and cultural contexts. A cross-sectional design limits the ability to establish causal relationships between anthropometric characteristics and linear growth. Therefore, longitudinal studies in future would provide more robust evidence of growth trajectories over time. Besides, the study may lack information on dietary habits, physical activity levels, and other lifestyle factors that could influence linear growth. Including such data in future would provide a more comprehensive understanding of the determinants of child growth. The findings can inform public health policies and interventions aimed at improving child nutrition and health outcomes in the region.

4. CONCLUSION

There was robust positive correlations between height and weight (r = 0.801) and between weight and BMI (r = 0.819). The height and BMI correlation was positive but moderate (r = 0.345). Over the 6 to 14 age range, boys experienced a weight increase of 32.4 kg (from 24.5 kg to 56.9 kg), and girls increased by 28.7 kg (from 21.7 kg to 50.4 kg). Height gain for boys was 46.3 cm (from 120.8 cm to 167.1 cm), while girls increased by 36 cm (from 118.8 cm to 154.8 cm). The BMI of boys rose by 3.7 kg/m² (from 16.7 kg/m² to 20.4 kg/m²), and girls increased by 6.0 kg/m² (from 15.3 kg/m² to 21.3 kg/m²). BMI for age z-score showed age-related fluctuations and this value was often higher in boys (ranging from 0 to 1.19) than in girls (ranging from -0.59 to 0.47). The variability in these anthropometric indicators differed significantly between boys and girls. Therefore, the growth of certain anthropometric characteristics in children and adolescents demonstrate positive outcomes. Finally, it is important to consistently monitor the growth of children, aligning with global child growth charts.

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NGHIỂN CỨU TĂNG TRƯỞNG TUYẾN TÍNH CỦA TRẺ EM:
KHÁM PHÁ ĐẶC ĐIỂM NHÂN TRẮC Ở TRẺ 6-14 TUỔI
TẠI THÀNH PHỐ THÁI NGUYỄN, VIỆT NAM

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Tóm tắt: Hiểu rõ các đặc điểm nhân trắc học của trẻ em là nền tảng để đưa ra các
biện pháp can thiệp y tế công cộng hiệu quả và xây dựng các chính sách nhằm
thúc đẩy phước lợi toàn diện. Nhiệm vụ này được tiến hành nhằm đánh giá một số
đặc điểm nhân trắc học bao gồm chiều cao, cân nặng và chỉ số khối cơ thể
(BMI) để đánh giá sự tăng trưởng tuyến tính của trẻ em từ 6-14 tuổi tại thành
phố Thái Nguyên. Nhiệm vụ này bao gồm 1.861 học sinh tại Trường Tiểu học
và THCS 915 Giang Sâm và Trường THCS Hoàng Văn Thụ cho thấy một tương
quan thuận chiều mảnh mé giữa chiều cao và cân nặng (r = 0,819). Chiều cao và BMI có
một tương quan thuận nhưng ở mức trung bình (r = 0,345). Trong đó tuổi từ 6-14,
cân nặng của học sinh nam tăng 32,4 kg (từ 24,5 kg lên 56,9 kg), và học sinh nữ tăng 28,7 kg (từ 21,7 kg lên 50,4 kg). Chiều cao ở nam tăng 46,3 cm (từ 120,8 cm lên 167,1 cm), trọng khi ở nữ tăng 36 cm (từ 118,8 cm lên 154,8 cm). Chỉ số BMI của học sinh nam tăng 3,7
kg/m² (từ 16,7 kg/m² lên 20,4 kg/m²), và học sinh nữ tăng 6,0 kg/m² (từ 15,3
kg/m² lên 21,3 kg/m²). BMI z-score theo độ tuổi cho thấy sự biến động theo tuổi.
Sự thay đổi các chỉ số nhân trắc học này khác nhau đáng kể giữa học sinh nam và
hoc sinh nữ. Như vậy, sự phát triển của một số đặc điểm nhân trắc học ở trẻ em
6 – 14 tuổi tại Thái Nguyên theo xu hướng tuyến tính và cơ sở tăng trưởng tích cực.
Do đó, phải theo dõi sự phát triển của trẻ một cách nhất quán, phù hợp với biểu
do tăng trưởng trẻ em toàn cầu.

Từ khóa: Tăng trưởng tuyến tính, đặc điểm nhân trắc học, trẻ em 6-14 tuổi,
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