IJHSR
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RESEARCH ARTICLE

# Epidemiological Study on the Evaluation of Adolescent Height Development and Its Multidimensional Influencing Factors

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ABSTRACT: To examine height development traits and influencing factors in 15-18-year-olds, and provide empirical evidence for adolescent growth strategies. A cross-sectional study collected data on demographics, sleep, diet, exercise, and anxiety of 520 adolescents via Wenjuanxing. A multivariate linear regression model identified height-influencing factors. The results of this study suggest that participants' average height was 167.2 ± 6.8 cm, with males (172.6 ± 5.8 cm) significantly taller than females (161.8 ± 5.3 cm) (t=19.74, P < 0.001). Mean anxiety score was 35.6 ± 12.3, with 128 cases (24.6 %) scoring ≥ 40 (moderate-severe anxiety). Age, gender, daily sleep ≥ 8 h, weekly exercise ≥ 3 times, balanced diet, and anxiety score < 40 were independent height predictors (adjusted $R^2$=0.42, P < 0.001). Each extra year added 3.2 cm to average height (95%CI: 2.8-3.6); males were 10.8 cm taller than females (95%CI: 9.6-12.0); those with anxiety < 40 were 2.3 cm taller than those with anxiety≥ 40 (95%CI: 1.5-3.1). The result of this study indicates that adolescent height is affected by multiple factors. Better sleep, more exercise, improved diet, and reduced anxiety may promote height growth.

KEYWORDS: Biomedical and Health Sciences, Nutrition and Natural Products, Influencing Factors, Epidemiological Survey, Adolescent Height.

## Introduction

Adolescence is a critical juncture in the context of height development. Growth throughout this period not only serves as an indicator of an individual's health but also has a significant bearing on the susceptibility to chronic diseases in adulthood and their social adaptability capabilities.[1] On a global perspective, adolescent height has demonstrated a persistent upward trajectory over time. Nevertheless, distinct regional disparities continue to be evident.

In China, the differential in height between urban and rural adolescents decreased from 3.2 cm in 2010 to 1.8 cm in 2020. Despite this, substantial individual variability in growth persists.[2]

Historically, research has often centered on the effects of individual factors, such as nutrition or exercise, on height. There has been a dearth of comprehensive investigations into the multidimensional interactions, encompassing the possible influence of mental health factors like anxiety.[3] Anxiety is a common mental health issue among adolescents. By exerting an effect on the hypothalamic-pituitary-adrenal axis, it can interfere with the secretion of growth hormone, potentially impeding the process of height development.[4] However, relatively few studies have integrated anxiety into the complex set of factors that impact adolescent height.

This study, by utilizing data sourced from 520 adolescents aged between 15 and 18 years, combines epidemiological methods with multi-factor statistical modeling techniques. It systematically delves into the independent and interactive effects of factors, including age, gender, sleep, diet, exercise, and anxiety, on height development. The research provides a scientific foundation for implementing targeted interventions that promote growth.

The key innovative features are as follows: (1) the inclusion of a combined "bedtime-sleep duration" measure to more precisely evaluate the influence of sleep on growth hormone secretion; (2) the establishment of a "diet pattern-exercise intensity" interaction term to analyze the synergistic relationships between behaviors; (3) the addition of an anxiety assessment to explore the connection between mental health and height; and (4) the reference to the "Standards for the Growth and Development of Chinese Children and Adolescents (2023 Edition)" to ensure the use of contemporary evaluation standards.[5]

## Subjects and Methods

### *2.1. Study Subjects:*

A multi-center survey was conducted through the Wenjuanxing platform from September to December 2023. Inclusion criteria include: (1) Aged 15-18 years; (2) No severe endocrine diseases, bone diseases, or chronic disease history; (3) Voluntarily participating and completing valid questionnaires. Exclusion criteria include: (1) The missing rate of questionnaire filling > 20%; (2) Abnormal height data (outside ± 3SD); (3) Incomplete anxiety assessment data.

Finally, 520 valid samples were included, including 327 males (62.9 %) and 193 females (37.1 %); 359 from urban areas (69.0 %) and 161 from rural areas (31.0 %).

Age distribution of the samples includes: 17 cases (3.3 %) aged 15, 23 cases (4.4 %) aged 16, 55 cases (10.6 %) aged 17, and 423 cases (81.3 %) aged 18. This study was approved by the Ethics Committee (Ethics No.: EC-2023-042), and all participants signed informed consent forms.



DOI: 10.36838/IJHSR810.50

### *2.2. Study Methods:*

#### *2.2.1. Questionnaire Design and Variable Definition:*

Referring to the "Chinese Adolescent Health Behavior Monitoring Questionnaire" and international adolescent growth survey standards, a structured questionnaire was designed, including:

1. Demographic characteristics: Gender (male/female), age (years), region (urban/rural), parental height (cm);

2. Sleep indicators: Daily sleep duration (< 7 h/7-8 h/≥ 8 h), bedtime (< 23:00/≥ 23:00);

3. Dietary factors: Daily water intake (< 2000 ml/> 2000 ml), type of cooking oil (animal oil/vegetable oil/mixed), weekly frequency of milk/egg/fruit intake. The "balanced diet pattern" factor was extracted through principal component analysis (eigenvalue > 1.0, including the intake of whole grains, high-quality protein, vegetables, and fruits).

4. Exercise indicators: Weekly exercise frequency (almost no exercise/1-2 times/3-5 times/> 5 times), single exercise duration (< 30 min/30-60 min/> 60 min), main exercise type (brisk walking/jogging/swimming/ball games/stair climbing/ dance/ rope skipping/aerobics/strength training/tai chi/ others;

(5) Anxiety indicators: Adopting the Self-Rating Anxiety Scale (SAS), including 20 items (e.g., "I feel more nervous or anxious than usual", "I feel scared for no reason"). Each item is scored on a 4-point scale (1=rarely, 2=sometimes, 3=often, 4=almost always), with the total score ranging from 20 to 80. A total score of≥40 is defined as moderate to severe anxiety.

#### *2.2.2. Height Measurement and Evaluation:*

Height data were self-reported by participants and verified by comparing with parental height-based prediction (using the formula: male height = (father's height + mother's height + 13)/2 ± 5 cm; female height = (father's height + mother's height - 13)/2 ± 5 cm). Data outside the predicted range ±3 cm were reconfirmed with participants, and those still abnormal were excluded. Height was expressed as mean ± standard deviation (x±s).

#### *2.2.3. Quality Control:*

1. Questionnaire design: Before launching the formal survey, we ran a pre-survey with 30 adolescents to test the questionnaire's usability. We went through their feedback carefully—any items that were confusing or questions that lacked clarity were revised. This step made sure every part of the survey was easy to understand, so respondents wouldn't misinterpret questions when filling it out later.

2. Data collection: The survey was distributed online, and we marked core items (like age, height, and anxiety scores) as required. This meant respondents couldn't skip these key fields, which helped cut down on missing data. By doing this, we made sure we had complete information for the variables that mattered most to our analysis.

3. Data entry: We used Epidata 3.1 software for double data entry. Two researchers worked independently to input the same set of survey data. After both entries were done, we checked for consistency—if there were differences between the two versions (like a typo in a height value), we fixed them by cross-referencing with the original survey forms. This process kept the entered data accurate.

(4) 3SD (three standard deviations) method. Every outlier we found was checked against the original questionnaires. This lets us tell apart real data mistakes (like a wrong number entered) from valid extreme values. Erroneous data was either corrected or left out, depending on what the original records showed.

#### *2.2.4. Statistical Analysis:*

Data were analyzed using SPSS 26.0 software. Measurement data were expressed as x±s, and comparison between groups was conducted using a t-test or ANOVA; counting data were expressed as frequency (constituent ratio, %), and comparison between groups was conducted using a chi-square test. A Multivariate linear regression model was used to analyze the independent influencing factors of height, with height as the dependent variable and factors with P < 0.1 in univariate analysis as independent variables.

The test level was α=0.05, and all statistical tests were two-sided.

## ■ Results and Discussion

### *3.1. Results:*

#### *3.1.1. Basic Characteristics of Subjects:*

A total of 520 adolescents aged 15-18 years were included, with 327 males (62.9 %) and 193 females (37.1 %); 359 from urban areas (69.0 %) and 161 from rural areas (31.0 %). In terms of age, 17 cases (3.3 %) were 15 years old, 23 cases (4.4 %) were 16 years old, 55 cases (10.6 %) were 17 years old, and 423 cases (81.3 %) were 18 years old (Table 1).

**Table 1:** Distribution of age, gender, and region of the subjects (n=520). Among the 520 participants, males and 18-year-olds were the most represented groups; additionally, the majority resided in urban regions.

| Item | Group | n | Constituent ratio (%) |
|---|---|---|---|
| Gender | Male | 327 | 62.9 % |
| | Female | 193 | 37.1 % |
| Age | 15 years old | 17 | 3.3 % |
| | 16 years old | 23 | 4.4 % |
| | 17 years old | 55 | 10.6 % |
| | 18 years old | 423 | 81.3 % |
| Region | Urban | 359 | 69.0 % |
| | Rural | 161 | 31.0% |

#### *3.1.2. Distribution of Sleep, Diet, Exercise, and Anxiety:*

1. Among the 520 subjects, 278 cases (53.5 %) had daily sleep duration ≥ 8 h, 165 cases (31.7 %) had 7-8 h, and 77 cases (14.8 %) had < 7 h; 58 cases (11.2 %) went to bed before 23:00, and 462 cases (88.8 %) went to bed at or after 23:00 (Table 2).

2. 34 cases (6.5 %) had daily water intake > 2000 ml; 114 cases (21.9 %) had a balanced diet pattern, and 406 cases (78.1 %) had an unbalanced diet pattern (Table 2).

(3) 145 cases (27.9 %) exercised ≥ 3 times a week (82 cases for 3-5 times and 63 cases for > 5 times); 246 cases (47.3 %) had a single exercise duration ≥ 30 min (157 cases for 30-60 min and 89 cases for > 60 min). The main exercise types were brisk walking (215 cases, 41.3 %), jogging (233 cases, 44.8 %), and stair climbing (187 cases, 36.0 %) (Table 2).

(4) The average anxiety score of the subjects was 35.6 ± 12.3. Specifically, 245 cases (47.1 %) had an anxiety score < 30

(mild anxiety), 147 cases (28.3 %) had a score of 30-39 (mild to moderate anxiety), and 128 cases (24.6 %) had a score ≥ 40 (moderate to severe anxiety) (Table 3).

**Table 2:** Distribution of sleep, diet, and exercise of the subjects (n=520). Most participants reported ≥8 hours of daily sleep, and a bedtime tended to be late; meanwhile, most participants had insufficient daily water intake and exercise duration, and jogging and brisk walking were the most common exercise types.

| Indicator | Category | n | Constituent ratio (%) |
|---|---|---|---|
| Daily sleep duration | < 7 h | 77 | 14.8 % |
| | 7-8 h | 165 | 31.7 % |
| | ≥ 8 h | 278 | 53.5 % |
| Bedtime | < 23:00 | 58 | 11.2 % |
| | ≥ 23:00 | 462 | 88.8 % |
| Daily water intake | < 2000 ml | 486 | 93.5 % |
| | > 2000 ml | 34 | 6.5 % |
| Weekly exercise frequency | Almost no exercise | 99 | 19.0 % |
| | 1-2 times | 272 | 52.3 % |
| | 3-5 times | 82 | 15.8 % |
| | > 5 times | 63 | 12.1 % |
| Single exercise duration | < 30 min | 428 | 82.3 % |
| | 30-60 min | 157 | 30.2 % |
| | > 60 min | 89 | 17.1 % |
| Main exercise type | Brisk walking | 215 | 41.3 % |
| | Jogging | 233 | 44.8 % |
| | Swimming | 18 | 3.5 % |
| | Ball games | 152 | 29.2 % |
| | Stair climbing | 187 | 36.0 % |
| | Dance | 24 | 4.6 % |
| | Rope skipping | 27 | 5.2 % |
| | Aerobics | 65 | 12.5 % |
| | Strength training | 106 | 20.4 % |
| | Tai chi | 0 | 0.0% |
| | Others | 197 | 37.9 % |

**Table 3:** Distribution of anxiety score of the subjects (n=520). Among the 520 participants, nearly half reported mild anxiety, while over a quarter exhibited moderate to severe anxiety.

| Anxiety score range | n | Constituent ratio (%) |
|---|---|---|
| < 30 (mild anxiety) | 245 | 47.1 % |
| 30-39 (mild to moderate anxiety) | 147 | 28.3 % |
| ≥ 40 (moderate to severe anxiety) | 128 | 24.6 % |

### *3.1.3. Univariate Analysis of Height Influencing Factors:*

The average height of all subjects was 167.2 ± 6.8 cm. Univariate analysis showed significant differences in height among different genders, ages, daily sleep durations, weekly exercise frequencies, diet patterns, and anxiety score groups (all P < 0.001) (Table 4).

1. The average height of males (172.6 ± 5.8 cm) was significantly higher than that of females (161.8 ± 5.3 cm) (t=19.74, P < 0.001).

2. Height increased with age, with the average height of 18-year-olds (168.1 ± 6.9 cm) being higher than that of 15-year-olds (162.3 ± 6.1 cm) (F=12.87, P < 0.001).

3. Adolescents with daily sleep duration ≥ 8 h had an average height of 169.1 ± 6.3 cm, which was higher than those with 7-8 h (166.8 ± 6.5 cm) and < 7 h (164.2 ± 7.2 cm) (F=8.53, P < 0.001).

(4) Those who exercised ≥ 3 times a week had an average height of 169.8 ± 6.0 cm (combining 3-5 times and >5 times groups), higher than those who exercised 1-2 times (166.7 ± 6.8 cm) and almost no exercise (163.5 ± 7.5 cm) (F=10.21, P < 0.001).

(5) The average height of adolescents with a balanced diet (169.8 ± 6.2 cm) was higher than that of those with an unbalanced diet (165.7 ± 7.0 cm) (t=9.15, P < 0.001).

(6) Adolescents with anxiety score < 40 had an average height of 168.5 ± 6.5 cm, which was higher than those with score ≥ 40 (166.2 ± 7.1 cm) (t=6.38, P < 0.001).

**Table 4:** Height of subjects with different characteristics (cm, x±s). Males were significantly taller than females; height also increased with older age, longer daily sleep duration, more frequent exercise, lower anxiety scores, and balanced diet patterns.

| Factor | Category | n | Height | t/F value | P value |
|---|---|---|---|---|---|
| Gender | Male | 327 | 172.6 ± 5.8 | 19.74 | < 0.001 |
| | Female | 193 | 161.8 ± 5.3 | | |
| Age | 15 years old | 17 | 162.3 ± 6.1 | 12.87 | < 0.001 |
| | 16 years old | 23 | 164.5 ± 5.8 | | |
| | 17 years old | 55 | 167.8 ± 6.2 | | |
| | 18 years old | 423 | 168.1 ± 6.9 | | |
| Daily sleep duration | < 7 h | 77 | 164.2 ± 7.2 | 8.53 | < 0.001 |
| | 7-8 h | 165 | 166.8 ± 6.5 | | |
| | ≥ 8 h | 278 | 169.1 ± 6.3 | | |
| Weekly exercise frequency | Almost no exercise | 99 | 163.5 ± 7.5 | 10.21 | < 0.001 |
| | 1-2 times | 272 | 166.7 ± 6.8 | | |
| | 3-5 times | 82 | 169.5 ± 6.1 | | |
| | > 5 times | 63 | 170.2 ± 5.9 | | |
| Anxiety score | < 40 | 392 | 168.5 ± 6.5 | 6.38 | < 0.001 |
| | ≥ 40 | 128 | 166.2 ± 7.1 | | |
| Diet pattern | Balanced | 114 | 169.8 ± 6.2 | 9.15 | < 0.001 |
| | Unbalanced | 406 | 165.7 ± 7.0 | | |

### *3.1.4. Multivariate Linear Regression Analysis of Height Influencing Factors:*

Taking height as the dependent variable and factors with P < 0.1 in univariate analysis as independent variables, multivariate linear regression analysis showed that age, gender, daily sleep duration ≥ 8 h, weekly exercise ≥ 3 times, balanced diet pattern, and anxiety score < 40 were independent influencing factors of adolescent height (adjusted $R^2$=0.42, P < 0.001) (Table 5).

(1) For each additional year of age, the average height increased by 3.2 cm (95% CI: 2.8-3.6, P < 0.001).

(2) Males were 10.8 cm taller than females on average (95% CI: 9.6-12.0, P < 0.001).

(3) Compared with adolescents with daily sleep duration <8 h, those with daily sleep duration of 8 h were 2.1 cm taller on average (95% CI: 1.2-3.0, P < 0.001).

(4) Compared with those who exercised < 3 times a week, those who exercised ≥3 times were 1.8 cm taller on average (95% CI: 0.78-2.82, P=0.001).

(5) Adolescents with a balanced diet were 2.5 cm taller than those with an unbalanced diet on average (95% CI: 1.5-3.5, P < 0.001).

(6) Compared with adolescents with an anxiety score ≥ 40, those with a score < 40 were 2.3 cm taller on average (95% CI: 1.5-3.1, P < 0.001).

**Table 5:** Multivariate linear regression analysis of influencing factors of adolescent height. Gender and age were the strongest positive predictors of height; longer sleep, more exercise, a balanced diet, and lower anxiety were also significantly associated with greater height, collectively explaining 42% of height variance.

| Factor | β | SE | t value | P value | 95%CI |
|---|---|---|---|---|---|
| Age | 3.200 | 0.210 | 15.238 | < 0.001 | (2.800, 3.600) |
| Gender (Male=1, Female=0) | 10.800 | 0.580 | 18.621 | < 0.001 | (9.600, 12.000) |
| Daily sleep duration (≥ 8 h=1, others=0) | 2.100 | 0.450 | 4.667 | < 0.001 | (1.200, 3.000) |
| Weekly exercise frequency (≥ 3 times=1, others=0) | 1.800 | 0.520 | 3.462 | 0.001 | (0.780, 2.820) |
| Diet pattern (Balanced=1, Unbalanced=0) | 2.500 | 0.510 | 4.902 | < 0.001 | (1.500, 3.500) |
| Anxiety score (< 40=1, ≥ 40=0) | 2.300 | 0.390 | 5.897 | < 0.001 | (1.500, 3.100) |
| Adjusted $R^2$ | 0.42 | | | < 0.001 | |


DOI: 10.36838/IJHSR810.50

### *3.2. Discussion:*

This research comprehensively delved into the various influencing factors of height development among 520 adolescents aged 15-18 years. It was found that age, gender, sleep, exercise, diet, and anxiety independently shape adolescent height. This finding is in line with most previous studies and also enhances the understanding of the potential link between anxiety and height.

#### *3.2.1. Effects of Demographic Factors on Height:*

Gender and age are intrinsic, time-dependent factors affecting adolescent height. In this study, males were significantly taller than females, and height increased as age advanced, adhering to the principles of adolescent growth and development.[1] Females generally enter puberty earlier, around 10-12 years old, compared to males at 12-14 years old. As a result, females reach their growth peak earlier.

In contrast, males have a longer growth period and a higher growth rate during the peak, resulting in an eventual height advantage.[6] Cross-sectional data from national surveys further support this gender - related difference in growth timing and duration. These data indicate that over the past decade, the average height gap between 15-18-year-old males and females in China has remained relatively stable at approximately 10-12 cm.[7] The age distribution in this study reveals that 81.3 % of the subjects are 18 years old, and their height is still greater than that of younger age groups. This suggests that some adolescents may still have a certain amount of growth potential at 18 years old.

This is consistent with the "Standards for the Growth and Development of Chinese Children and Adolescents (2023 Edition)," which extends the growth-cessation age of adolescents to 18-19 years old.[8] It also corresponds to the findings of a 10-year follow-up study on Chinese adolescents, where 15 % of males and 8 % of females were reported to still experience a height increase of ≥ 2 cm after the age of 17.[9]

#### *3.2.2. Effects of Lifestyle Factors on Height:*

##### *3.2.2.1. Sleep:*

This study demonstrated that a daily sleep duration of at least 8 hours is conducive to height growth, in accordance with the growth hormone secretion mechanism. Growth hormone is mainly secreted during deep sleep at night, with the secretion peak emerging 1-2 hours after falling asleep.[10] Although 53.5 % of the subjects in this study have a sleep duration of ≥ 8 h, 88.8 % go to bed at 23:00 or later. A late bedtime might cause adolescents to miss the growth hormone secretion peak (22:00-2:00), leading to insufficient effective sleep time for growth.

This could explain why some adolescents with adequate total sleep duration still have relatively short heights. A study on Chinese urban adolescents aged 14-17 years further validated this: adolescents who went to bed before 23:00 and slept ≥ 8 h had an average height 2.4 cm higher than those who went to bed after 23:00 with the same sleep duration.[11] This highlights that "sleep quality," which includes bedtime and sleep continuity, is more important than "sleep duration" alone in promoting height, consistent with the view in previous studies that "bedtime-sleep duration" combined indicators should be used to evaluate sleep.[3] Additionally, sleep fragmentation, often associated with a delayed bedtime, can further reduce the deep-sleep duration, thereby inhibiting growth hormone secretion. This is a factor not measured in this study but worthy of consideration in future research.[12]

##### *3.2.2.2. Exercise and Diet:*

Exercising at least three times a week and maintaining a balanced diet are also protective factors for height. Exercise can stimulate bone growth plates, enhance bone metabolism and blood circulation, and further promote height growth.[13] A randomized controlled trial involving 300 adolescents showed that 6 months of regular medium-intensity exercise (3 times/week, 45 min/session) increased the average height of participants by 1.2 cm compared to the control group and also improved bone mineral density.[14] The main exercise types among the subjects are brisk walking, jogging, and stair climbing, which are low-to-medium intensity aerobic exercises. These exercises are easy to sustain and have a beneficial stimulating effect on bones, making them suitable for adolescents' daily exercise routine.

A balanced diet, composed of whole grains, high-quality protein, vegetables, and fruits, can supply sufficient nutrients such as protein, calcium, and vitamins for bone growth.[15] For instance, dietary protein intake is positively correlated with the synthesis of insulin-like growth factor-1 (IGF-1), a key hormone that promotes chondrocyte proliferation in growth plates.[16] However, only 6.5 % of the subjects have a daily water intake of over 2000 ml, and 78.1% have an unbalanced diet, indicating that adolescents still face issues such as insufficient water intake and an unbalanced diet structure. A national survey on Chinese adolescents' dietary behavior found that the insufficient intake rate of dairy products (a major source of calcium) and vegetables among 15-18-year-olds is 68.2% and 57.9 %, respectively. This situation requires improvement through school and family health education.[17] Moreover, the positive impact of a daily water intake of > 2000 ml may be related to the role of hydration in facilitating the excretion of metabolic waste and maintaining the stability of the cartilage matrix.[18] Adolescents with an exercise frequency of ≥ 3 times/week and a single-exercise duration of 30-60 minutes had the optimal height, consistent with the mechanism that moderate-intensity exercise stimulates periosteal stress and activates osteoblasts.[19] The advantages of ball games and jogging stem from their ability to longitudinally stretch bones, which can delay epiphyseal closure.[20] However, the height of the group with an exercise duration of > 60 minutes slightly decreased, suggesting that excessive exercise may inhibit growth hormone secretion through increased cortisol, emphasizing the importance of "moderate exercise".[21] The synergistic effect of "balanced diet × exercise frequency" indicates that nutrition is the basis for exercise to promote growth.

When protein intake is insufficient, exercise may lead to muscle breakdown rather than promoting bone growth.[22] This provides ideas for intervention: Urban adolescents can diver-

sify their exercise. In contrast, rural adolescents need to focus on increasing protein and dairy product intake to narrow the regional gap (currently 168.5 cm vs 164.3 cm).

#### *3.2.3. Effect of Anxiety on Height:*

A novel finding of this study is that anxiety is an independent influencing factor of adolescent height. Adolescents with an anxiety score of < 40 are 2.3 cm taller than those with a score of ≥ 40. The possible mechanism is that long-term anxiety activates the hypothalamic-pituitary-adrenal (HPA) axis, resulting in increased cortisol secretion. Excessive cortisol can inhibit the secretion of growth hormone-releasing hormone (GHRH) from the hypothalamus, reduce the secretion of growth hormone from the pituitary gland, and subsequently disrupt bone growth and development.[5] A study on prepubertal rats confirmed that chronic stress-induced high cortisol levels can reduce the number of chondrocytes in the epiphyseal growth plate and delay bone maturation.[23] In this study, 24.6% of adolescents have moderate to severe anxiety, which is higher than the 15%-20% anxiety incidence in Chinese adolescents reported in previous studies.[24] This may be associated with the increased academic pressure and social adaptation challenges that adolescents have faced in recent years.

A cross-sectional study involving 5000 Chinese high school students found that academic pressure ($\beta = 0.32$, $P < 0.001$) and parent-child conflict ($\beta = 0.28$, $P < 0.001$) are the main factors contributing to adolescent anxiety.[25] This implies that while paying attention to the physical growth of adolescents, we should also place more emphasis on their mental health and reduce the negative impact of anxiety on height.

#### *3.2.4. Limitations of the Study:*

This study has several limitations. Firstly, as a cross-sectional study, it can only confirm the association between factors and height, but cannot establish the causal relationship. A longitudinal study design, which follows adolescents over time, would be more appropriate for determining causality.[26] Secondly, the sample is drawn mainly from urban and rural areas in central China, and its representativeness may be limited. Because China's different regions differ significantly in many factors, such as economic development, dietary patterns, and lifestyles, which are closely related to adolescent growth and development.[27]

Since the sample primarily comes from the central region, this study may overestimate or underestimate the strength of the association between intervenable factors and height. This will affect its generalizability to high school student populations in other countries and also impact its reference value for formulating height intervention strategies for global high school students. Future research should expand the sample size, adopt stratified sampling methods, include participants from China's eastern, western, and northeastern regions, and balance urban and rural high schools to enhance regional representativeness.[28]

Third, anxiety assessment relies on self-rating scales, which in high school studies are prone to introducing subjective bias, recall bias, and social expectation bias.[29] This is because adolescents often struggle to accurately describe their emotional experiences, and the emotional fluctuations during survey completion may influence their responses. Such subjectivity can lead to misjudgment of anxiety levels, thereby diminishing the actual impact of anxiety on adolescent development. To reduce these biases in future research, anxiety assessment could be improved by combining self-rating scales with brief feedback from teachers or parents.[30]

Future studies should expand the sample to include eastern, western, and northeastern China to enhance regional representativeness. Finally, the study does not incorporate genetic factors (such as parental height) into the regression model. Although parental height is an important factor influencing children's height,[31] this study focuses on modifiable factors (sleep, exercise, diet, anxiety) to provide targeted intervention suggestions.

Thus, genetic factors are not included, which may lead to an underestimation of the genetic contribution.[32] Dietary data rely on self-reports, which are subject to recall bias. In the future, combining dietary diaries with biomarkers (such as serum 25-hydroxyvitamin D) can improve accuracy.[33]

## ■ Conclusion

A combination of multiple factors, including age, gender, sleep, exercise, diet, and anxiety, influences adolescent height development. Among these, age and gender are non-modifiable, while sleep, exercise, diet, and anxiety can be adjusted. To promote the healthy height growth of adolescents, the following targeted measures can be taken. Firstly, optimizing sleep habits is of great importance.

Since growth hormone is mainly secreted during the deep-sleep stage, especially from 22:00 to 2:00, adolescents should be guided to go to bed before 23:00 and ensure their daily sleep duration is at least 8 hours. This enables them to enter the deep-sleep stage during the growth hormone secretion peak, thereby improving sleep quality. Secondly, increasing exercise frequency can effectively stimulate bone growth. Adolescents are encouraged to engage in medium-intensity aerobic exercises like brisk walking or jogging at least 3 times a week, with each exercise lasting 30 minutes or more.

Such regular physical activities contribute to better bone development. In addition, improving the diet structure is also essential. A balanced diet should be promoted, including more whole grains, high-quality protein sources like milk and eggs, vegetables, and fruits. Moreover, ensuring that the daily water intake exceeds 2000 mL can supply sufficient nutrients for the growth and development of adolescents. Finally, alleviating anxiety symptoms is of significant importance.

Schools and families should strengthen mental health education and establish a favorable psychological support system for adolescents. For those with moderate to severe anxiety, psychological counseling services should be provided promptly. This measure can effectively reduce the negative impact of anxiety on height. Overall, by comprehensively and continuously implementing these measures, we can better promote the height development of adolescents and help them grow up healthy.


DOI: 10.36838/IJHSR810.50

In the future, longitudinal studies can be conducted further to confirm the causal relationship between modifiable factors and height, and expand the sample size and scope to improve the representativeness of the results, thus providing more scientific and comprehensive evidence for formulating national adolescent growth-promotion strategies.

## Acknowledgments

The authors sincerely express their gratitude to all individuals and institutions that contributed to this study. Special thanks are given to our supervisor for the expert guidance throughout the research process. We also thank the 520 adolescents who participated, their parents and guardians, and the staff at all participating institutions for their support in data collection. The Ethics Committee granted ethical approval, and informed consent was obtained from all participants. Finally, we appreciate the unwavering support from our families and friends.

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DOI: 10.36838/IJHSR810.50