Health Promotion and Physical Activity
ISSN 2544-9117 ▪ 2025; 31 (1): 1-6
doi: 10.55225/hppa.646

HPPA • 2025; 31 (2): 1-6

# Verification of selected methods of body height prediction for male and female pupils on the example of students of the Upper Secondary School Complex No. 2 in Dąbrowa Tarnowska, Poland

Patryk Orwat[1] A-F, Ryszard Żarów[1,2] A,C-G

[1] University of Applied Sciences in Tarnow, Faculty of Medicine and Health Sciences, Tarnów, Poland
[2] University of Physical Culture in Kraków, Faculty of Physical Education and Sport, Department of Anthropology, Kraków, Poland

## Abstract

**Aim:** The aim of the study was to assess the magnitude of error in the prediction of adult body height of male and female pupils from the Upper Secondary School Complex No. 2 in Dąbrowa Tarnowska using the Roche-Wainer-Thissen, Khamis-Roche and Żarów methods.

**Material and methods:** Data on the height and weight of 101 18-year-old pupils (54 female pupils and 47 male pupils), as well as parental mean body height, were used in the study. The pupils' height and weight data came from screening tests performed at 6.5, 10 and 12 years of age by nurses and school hygienists, while the data on parents' height was obtained through written notes provided by the students.

**Results:** An evaluation of the prognostic methods carried out showed differences in prognostic performance depending on the method, the age of the predicted body height and gender. An analysis of the distribution of the absolute error of prognosis at the age of 10 showed that as many as 71% of all prognoses showed an error of less than 3 cm in relation to the actual body height at age 18, which should be considered a very good result in clinical or school practice setting.

**Conclusion:** Based on the analysis of the results, it was found that models based on data from the ages of 10 to 12 years provided the highest accuracy for predicting adult body height. The Żarów Model for male pupils and the Khamis-Roche Model for female pupils show the lowest mean prediction error. The models are the most accurate for individuals with a typical developmental trajectory, and their performance decreases in extreme cases (very tall and very short children).

Original article

## Keywords

- body height prediction
- Roche-Wainer-Thissen Method
- Khamis-Roche Method
- Żarów Method
- school children
- adolescents

## Contribution

A – Preparation of the research project
B – Assembly of data
C – Conducting of statistical analysis
D – Interpretation of results
E – Manuscript preparation
F – Literature review
G – Revising the manuscript

## Corresponding author

**Ryszard Żarów**
e-mail: ryszard.zarow@akf.krakow.pl
Akademia Kultury Fizycznej
im. B. Czecha w Krakowie
Wydział Wychowania Fizycznego i Sportu
Instytut Nauk Biomedycznych
Zakład Antropologii
Al. Jana Pawła II 78, 31-571 Kraków, Poland
tel. +48 12 683 13 25

Article info

### Article history

- Received: 2025-07-10
- Accepted: 2025-07-23
- Published: 2025-07-29

### Publisher

University of Applied Sciences in Tarnow
ul. Mickiewicza 8, 33-100 Tarnow, Poland



### Conflict of interest

None declared.

### Financing

This research did not receive any grants from public, commercial or non-profit organizations.

## Introduction

Body height has been recognised for decades as one of the key objective indicators of somatic development in children and adolescents and an important diagnostic parameter in paediatrics, school medicine and sport.[1,2] Its assessment is applicable both at the individual level, allowing the identification of developmental deviations, and in population-based studies, where it reflects the general state of health and well-being of children in a given country or region.[3,4]

The analysis of child and adolescent growth plays an important role in assessing the effectiveness of health policies, environmental conditions and socio-economic changes.[1,3] This indicator is sensitive to a variety of factors ranging from genetics, nutrition, physical activity, quality of healthcare, to broader living conditions.[5,6] In the last decades, Poland, like other developed countries, has seen the so-called secular phenomenon, i.e. a systematic increase in the average body height of children and adolescents, resulting from improved living conditions and public health.[7] Body height, being a determinant of normal biological development, is not only an object of observation, but increasingly also of prognosis – both for clinical and practical purposes: educational, sporting or psychological. In medicine and psycho-educational counselling, the ability to predict future growth allows early detection of potential developmental disorders and the implementation of preventive or therapeutic measures.[1]

In sport, body height prediction is used in selection for disciplines requiring specific somatic conditions and in individualising the training process and developmental support.[1,8,9] In Poland, predictive tools have been used for many years to predict adult body height already at the stage of childhood or early adolescence. Among the best known are the Milicerova, Roche-Wainer-Thissen (RWT), Khamis-Roche (KR) Models and the Żarów (Z) Model, based on national population data and recommended for use in Polish settings.[1,10,11,12] The accuracy of these models sometimes varies, depending on the age of the child at the time of prediction, the completeness of the input data (especially about the parents) and whether the model has been validated on a population with similar environmental and genetic conditions.[3,13,14] It is particularly important to validate predictive tools in local populations and to compare their results with current norms of somatic development in children and adolescents. In Poland, such a function is performed by the percentile grids of the OLAF project, determined on the basis of nationwide population studies and now widely used in clinical and school practice.[3] Comparison of the effectiveness of the predictive models with the OLAF project's reference values allows not only the verification of the tools, but also the analysis of regional differences and the identification of environmental factors influencing the course of child and adolescent growth.[3]

The aim of the study was to evaluate and compare the magnitude of the error in the prediction of adult body height in male and female pupils from the Upper Secondary School Complex No. 2 in Dąbrowa Tarnowska using the Roche-Wainer-Thissen (RWT), Khamis-Roche (KR) and Żarów (Z) Methods.

## Material and methods

Data on body height and weight of 101 pupils of the Upper Secondary School Complex No. 2 in Dąbrowa Tarnowska and mean parental body height were used for the study considered. Data on pupils' height and weight came from screening tests conducted by nurses and school hygienists since the beginning of their education, while data on the height of both parents were obtained during school meetings. Male and female pupils aged 18 and over were selected for the study. At this age, both male and female pupils are at the end of their growth process. However, a certain portion of the population, especially late adolescents, still grow in height after the age of 18, as described by Żarów.[15]

Measurement data of 47 male and 54 female pupils were collected. The surveys were conducted in January and February 2019, while the data on parents' height was obtained through written notes provided by the students. Measurement data values from the screening tests were measured to the nearest 0.1 centimetre and 0.1 kilogram. Among the inclusion criteria were the following: having complete anthropometric data (height and weight) from the ages of 6.5, 10, 12 years, copied from the pupils' health cards, and verified height data from both parents, obtained during school meetings. Based on the data from the screening and using selected prediction methods, the pupils' predicted adult body height was calculated. These predictions were calculated on the basis of the values of body height and body weight reached by the pupils at 6.5, 10 and 12 years of age. Data collection was carried out after obtaining the required consent. Special care was taken to protect the anonymity and reliability of the data. Anthropometric measurements were carried out under school conditions, in accordance with current IMiD guidelines and standards used in the screening of children and adolescents in Poland.[3,16,17]

Three methods were used to determine predicted body height in adulthood: the Roche-Waimer and

Thissen (RWT) Method from 1975, the Khamis and Roche (KR) Method from 1994 and the Żarów (Z) Method from 2001. These methods allow to determine the body height that can be reached at the age of 18 years. All these methods take into account the same variables, such as chronological age, height and weight at the time of measurement and the average height of the parents; in addition, the RWT method uses skeletal age, which up to the age of 8 years for girls and 13 years for boys can be replaced by chronological age.[16] These variables are basic morphological parameters of every human being and their measurement is not diffiult, as specialised laboratory instruments and apparatus are not required for it. Simple measurements of somatic characteristics are an advantage for predicting body height in adulthood. The measurement of body height at the age of 18 years made it possible to verify the predicted body height at the ages of 6.5, 10 and 12 years with that actually achieved at the age of 18 years. Data were statistically analysed using the Statistica software and spreadsheets. Mean absolute error (in cm) was calculated for each participant and each method, in relation to actual height at age 18; distribution of prediction errors according to ranges (<3 cm, 3–5 cm, >5 cm).

# Results

The analysis of the prognostic methods carried out showed differences in prognostic performance depending on the method, the age of the predicted body height and gender. Detailed data are presented in Table 1.

The best prediction accuracy was achieved when using measurement data from the ages of 10 and 12 years, particularly for male pupils, where the Żarów Model gave a mean absolute error of 2.4 cm (age 10 years) and 2.5 cm (age 12 years) respectively. For the female pupils, the lowest prediction error was obtained using the Khamis-Roche method for age 12 data (1.9 cm). In contrast, predictions based on data for the age of 6.5 years, irrespective of method and gender, had a much higher mean error, exceeding 3 cm.

An exemplary analysis of the distribution of the absolute prediction error at age 10 years showed that as many as 71% of all predictions showed an error of less than 3 cm relative to the actual body height at age 18 years, which should be considered a very good result in a clinical or school practice setting.

**Table 1.** Mean absolute error of prognosis across gender and age, according to different methods of calculated prognosis of adult body height of students from the Upper Secondary School Complex No. 2 in Dąbrowa Tarnowska

| Female pupils | | | | Male pupils | | | |
|---|---|---|---|---|---|---|---|
| **Method*** | 6,5 years | 10 years | 12 years | **Method*** | 6,5 years | 10 years | 12 years |
| **RWT** | 3.20 | – | – | **RWT** | 3.10 | 2.74 | 3.20 |
| **KR** | 3.21 | 2.86 | 1.93 | **KR** | 3.53 | 3.01 | 3.00 |
| **Z** | 3.53 | 3.07 | 2.32 | **Z** | 3.09 | 2.38 | 2.49 |

*RWT – Roche-Waimer and Thissen's Method, KR – Khamis and Roche's Method, Z – Żarów Method.

**Table 2.** Distribution of absolute errors of prediction of adult body height of pupils from the Upper Secondary School Complex No. 2 in Dąbrowa Tarnowska at the age of 10 years according to different methods (N = 101)

| Range of prediction error (cm) | Percentage (%) |
|---|---|
| < 3 | 71 |
| 3–5 | 20 |
| >5 | 8 |

The largest errors of more than 5 cm appeared in cases where the prediction was conducted for children with variable growth rates. The highest reproducibility and accuracy of prediction in male pupils was shown by the Żarów Model, while among female pupils it was shown by the Khamis-Roche Model. In each method, predictions for ages 10–12 had significantly lower absolute error than predictions based on data from the age of 6.5. Regression models have the highest accuracy in children with body heights within the median for the population data, while their performance decreases in extreme cases (very short or very tall individuals). To further confirm the reliability of the sample and the concordance of the developmental trajectory, the mean body height of the children surveyed at the age of 8 years was interpolated from measurements at 6 and 10 years, and compared with the corresponding values from the OLAF project. The body height calculated in this way is 126.7 cm for girls and 129.6 cm for boys, and according to the OLAF project 130.3 and 131.5 cm respectively, confirming the conformity of the study group with national developmental trends.

## Discussion

The main characteristic of the study sample was the very close correlation of body height values with the current OLAF 3 project standards for Polish children and adolescents. Table 3 juxtaposes the mean values of body height in individual periods of the study with analogous reference values.

The results obtained confirm that the growth dynamics of the studied group reflects typical growth trajectories in the Polish population, for both male and female pupils, with lower values on average at the ages of 6.5, 10 and 12, especially for female pupils, which may be due to the size of the inhabited environment, Dąbrowa Tarnowska being a small town with a population of just over 11,000 and the School Complex being attended by pupils from the surrounding villages as well. Both in the present study and in other national studies, it has been confirmed that the greatest precision in body height prognosis is obtained using measurement data from late childhood or prepubertal period (10–12 years).[1,11]

**Table 3.** Average body height of the tested students from of the Upper Secondary School Complex No. 2 in Dąbrowa Tarnowska and average body height of male and female pupils according to the OLAF project

| Age (years) | Female (N = 54) | Female (OLAF) N | | Male (N = 47) | Male (OLAF) N | |
|---|---|---|---|---|---|---|
| 6.5 | 117.6 | 120.2* | 508 | 119.7 | 121.6* | 530 |
| 10 | 135.8 | 140.7 | 747 | 139.4 | 141.5 | 648 |
| 12 | 150.4 | 153.5 | 636 | 153.1 | 154.0 | 638 |
| 18 | 165.4 | 165.1 | 1126 | 180.7 | 179.5 | 846 |

*Weighted mean.

In the population studied, the mean prediction error did not exceed 1.9–3.1 cm (except for the RWT Method for girls aged 12 years), which should be considered a very good result from the point of view of clinical or school practice. The absolute error of the prediction is included in the paper, as it does not matter much if we overestimate or underestimate the predicted body height by, for example, +2.5 cm or –2.5 cm, in relation to the actual adult body height achieved.

It is worth noting that the effectiveness of the predictions clearly increases with input age – predictions based on data from the age of 6.5 years had a significantly higher error (within 3.0–3.6 cm), confirming the limited predictive value of models used in younger age groups. This is consistent with previous observations by both Polish and foreign authors, who also emphasised the need to update predictions with subsequent measurements as the child grows.[12] The analysis conducted confirmed that the Żarów Model – developed on the basis of Polish population data – shows the highest effectiveness in boys. This is consistent with the idea that prognostic tools adapted to local genetic and environmental conditions have higher accuracy than imported models.[3] In girls, the lowest error was obtained with the Khamis-Roche Model, indicating the good versatility of this method, even in populations with a different biological structure than the US population on which the KR Model is based. The observed differences may be due to the specific course of sexual maturation, the rate of somatic development and the different influence of environmental factors during adolescence in girls and boys.[18,19,20]

A number of works written after 2000 base adult height prediction on various mathematical models using girls' and boys' height growth curves[21,22,23] et al. Thus, in paper[21] authors developed a novel method, called Growth Curve Comparison (GCC), for height prediction, based on a large cohort of >16,000 Slovenian schoolchildren followed yearly from ages 8 to 18 and compared the GCC method to the percentile method, linear regression, decision tree regression and extreme gradient boosting. The average error of prediction according to the gradient curves between the ages of 8 and 12 was within about 3 cm, for both boys and girls. In paper,[23] the average difference between the predicted and actual height at the age of 17.5 years for a 95% confidence interval ranged from –3.2 cm to +2.8 cm, from which it could be estimated that the average absolute error of prediction would amount to approx. 3 cm. On the other hand, a paper by Chinese authors[22] on the study of a multidimensional and accurate model of adolescent height based on a multilayer perceptron shows that if the BMI calculated for a given chronological age and skeletal age is added to this multilayer perceptron, the accuracy of body height prediction improves. Although the average absolute error of

prediction between the ages of 6 and 15 was slightly more than 1 cm for both boys and girls, this is true for Chinese children and adolescents, as this model was developed for this population only. Predictions based on mathematical models are very intricate, hence they are rather rarely used, unlike those used in this study.

From a practical point of view, the quality and completeness of the input data – in particular height data of both the child and the parents – is crucial for the accuracy of the prediction. The study highlights the need for reliable collection of this information, verification of possible questionnaires and exclusion of questionable cases. Missing or inaccurate parental data is one of the main sources of prediction errors, which is also confirmed in the literature.[6,21]

The results obtained have a number of practical implications. First of all, they confirm that the prediction of adult height using the models described should be a routine part of the work of doctors, school nurses, physical education teachers, coaches and developmental guidance specialists. Early height prediction makes possible the optimisation of developmental support, faster detection of disorders and better sport selection. It is particularly important to periodically update the predictions with subsequent measurements, which increases the accuracy of the predictions and allows the intervention to be flexibly adapted to the individual situation of the child.

A limitation of the survey remains the local nature of the sample, which may affect the ability to predict results in other regions. Results may also depend to some extent on the specific environmental conditions of the region and the socio-economic structure of families.

In sports selection – especially in disciplines requiring specific somatic conditions (e.g. volleyball, basketball, swimming, some athletic competitions) – the prediction of future adult body height is an extremely valuable tool to support the decisions of coaches and physical education teachers. It allows not only the rational selection of athletes for particular disciplines, but also the planning of the path of sports development and the prediction of the moment of the child's highest developmental potential.

In the future, it is advisable to conduct research on larger and more diverse samples, covering different regions of Poland – both urban and rural environments. This will allow an even fuller examination of the effectiveness of predictive tools in different environmental conditions and the identification of factors that have the greatest impact on the accuracy of predictions.

## Conclusions

Based on the study and the analysis of the results, it can be concluded:

1. The highest accuracy in predicting adult body height is provided by models based on data from 10–12 years of age.
2. The Żarów Model for boys and the Khamis-Roche Model for girls show the lowest mean prediction error.
3. The models are most accurate for individuals with a typical developmental trajectory and their performance decreases in extreme cases (very tall and very short children).

## References

[1] Żarów R. *Prognozowanie dorosłej wysokości ciała chłopców: model własny i analiza porównawcza innych metod*. Kraków: Wydawnictwo AWF; 2001.

[2] Kopczyńska-Sikorska J, Mięsowicz I. Zastosowanie metody RWT do przewidywania ostatecznej wysokości ciała chłopców z prostym niedoborem wzrostu. *Probl Med Wieku Rozw*. 1982;11:45-50.

[3] Kułaga Z, Różdżyńska-Świątkowska A, Grajda A i in. Siatki centylowe dla oceny wzrastania i stanu odżywiania polskich dzieci i młodzieży od urodzenia do 18 roku życia. *Stand Med Pediatr*. 2015;12:119-135.

[4] Suliga E. Charakterystyka procesu wzrastania dzieci z prostym niedoborem wysokości ciała. In: Jopkiewicz A, ed. *Auksologia a promocja zdrowia*. Kielce: KTN; 1997:203-213.

[5] Woynarowska B, Palczewska I, Oblacińska A. Standardy WHO rozwoju fizycznego dzieci w wieku 0–5 lat. Siatki centylowe długości/wysokości i masy ciała, wskaźniki masy ciała BMI i obwodu głowy. *Med Wieku Rozw*. 2012;16(3):232-239.

[6] Szopa J, Mleczko E, Żak S. Podstawy antropomotoryki. Warszawa–Kraków: Wydawnictwo Naukowe PWN; 2000.

[7] Kopczyński M, Siniarska A, eds. *Budowa fizyczna człowieka na ziemiach polskich wczoraj i dziś*. Warszawa: Muzeum Historii Polski; 2017.

[8] Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity*. Leeds: Human Kinetics; 2004.

[9] Łaska-Mierzejewska T. Accuracy of adult height prediction. *Rocznik Nauk*. 1992;2:187-207.

[10] Milicerowa H. *Budowa somatyczna jako kryterium selekcji sportowej*. Warszawa: Polski Komitet Olimpijski; 1973.

[11] Roche AF, Thissen D, Wainer H. The RWT method for the prediction of adult stature. *Pediatrics*. 1975;56(6):1027-1033.

[12] Khamis HJ, Roche AF. Predicting adult stature without skeletal age: The Khamis-Roche Method. *Pediatrics*. 1994;94(4):504-507.

[13] WHO. *Physical status: The use and interpretation of anthropometry*. Geneva: World Health Organization; 1995.

[14] WHO. *Child Growth Standards: Length/height forage, weight for age, weight for length, weight for height and body mass index for age: Methods and development*. Geneva: World Health Organization; 2006.

[15] Żarów R. Analiza dorastania wysokości ciała chłopców. *Wych Fiz Sport*. 1995;4:11-18.

[16] Żarów R. Metody prognozowania dorosłej wysokości ciała. In: Chrzanowska M, Gołąb S, eds. *Przewodnik do ćwiczeń z antropologii*. Kraków: Wydawnictwo AWF; 2014:68-87.

[17] Jodkowska M, Woynarowska B, eds. *Testy przesiewowe u dzieci i młodzieży w wieku szkolnym*. Warszawa: Instytut Matki i Dziecka, Zakład Medycyny Szkolnej; 2002.

[18] Kaczmarek M, Wolański N. *Rozwój biologiczny człowieka: od poczęcia do śmierci*. Warszawa: Wydawnictwo Naukowe PWN; 2018.

[19] Malinowski A, ed. *Antropologia fizyczna*. Warszawa–Poznań: PWN; 1980.

[20] Niedźwiecka Z., Łaska-Mierzejewska T. Prevision de la taille adulte: comparaison de l'exactitude de la prevision staturale etablie selon les methodes de Milicer, TW2 et RWT. *Cahiers d'Anthropologie et Biometrie Humaine*. 1996;14(3-4):559-566.

[21] Żarów R. Ocena błędu prognozy dorosłej wysokości ciała dziewcząt według różnych metod przewidywania. *Wych Fiz Sport*. 1991;1:61-71.

[22] Mlakar M, Gradišek A, Luštrek M, Jurak G, Sorić, M, Leskošek B, Starc G. Adult height prediction using the growth curve comparison method. *PLoS One*. 2023;18(2):1-13. doi: 10.1371/journal.pone.0281960.

[23] Pineau JC. Longitudinal growth of stature in boys according to age and puberty. *Am J Hum Biol*. 2023;35(6):1-7. doi: 10.1002/ajhb.23877.

[24] Chen L, Fan X, Mao K, Tolba A, Alqahtani F., Ahmed AM. Study of multidimensional and high-precision height model of youth based on multilayer perceptron. *Comput Intell Neurosci*. 2022;1:1-11.doi: 10.1155/2022/7843455.