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RESEARCH ARTICLE

The Effect of Parental Height on a Child's Final Height in Turkish Society and the Validation of the Midparental Height Formula

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Abstract:

***Objective*:** This study aimed to assess the validity of the traditional midparental height (MPH) formula in predicting a child's final height in the Turkish population and to compare different models for better accuracy.

***Materials and Methods*:** A total of 988 university students (594 females, 394 males) and their parents were included in the study. Height measurements were obtained using a standardized ultrasonographic device. Various models based on MPH were tested, and the correlation between subject height, MPH, and parental heights was analyzed. Statistical analyses, including correlation and general linear models, were performed to determine the best model for predicting height.

***Results*:** The mean height of female students was 164.5 cm, while for males, it was 177.7 cm. On average, actual height exceeded MPH by 3.8 cm in females and 2.69 cm in males. Correlation analysis revealed moderate to strong associations between subject height and MPH ($r=0.537$ for girls, $r=0.487$ for boys). The best predictive model was found to be Model 4, which incorporated coefficients for maternal and paternal height, with distinct formulas for males and females.

***Conclusion*:** The traditional MPH formula demonstrated a significant prediction error in the Turkish population. Our study suggests that maternal and paternal heights influence final height differently based on gender and other factors. The model developed in this study offers better predictive accuracy but requires further validation in larger, diverse populations to confirm its global applicability.

Keywords: Traditional Midparental Height (MPH), standardized ultrasonographic device.

1. INTRODUCTION

Growth and height are regulated by genetic, hormonal and environmental factors [1]. Determination of genetic height potential is very important in the evaluation of patients with short stature, especially in the evaluation of familial short stature, which constitutes an important part of the etiology [2]. Midparental height (MPH) represents the height that the child is expected to attain according to his/her parents (*i.e.* genetic height potential). This concept was first introduced by Galton in 1886 and was calculated by averaging maternal and paternal height with the formula MPH=(Father's height+ Mother's height)/2 [3].

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Years later, Tanner *et al.* improved this concept by adding adjustments for gender [4]. This is the method that is still widely used.

Although the revision made by Tanner *et al.* was widely accepted, later studies have suggested that this revision does not take into account differences between countries or populations and the trend of the century and therefore is not open to global use [5,6]. For example, Fredriks *et al.* stated that differences of up to 4.5 cm could occur between the results calculated with this formula for the Dutch population and the actual findings, which they thought to be due to the trend of the century [5]. In their study published in Germany in 2003, Hermanussen and Cole proposed a new formula that takes into account the standard deviation scores (SDS) of maternal and paternal heights and considers the parent-child correlation in terms of final height [6]. Although many countries such as the Netherlands and Germany have tested how well MPH-based predictive models fit the reality of their populations and developed models accordingly, no similar study has been conducted in Turkey [5,6]. Therefore, in our study, we aimed to analyze how well the traditional concept of MPH fits our population and which of the different possible models based on MPH is more valid for our population.

2. MATERIALS AND METHODS

Approval for our study was obtained from Medipol University Non-Interventional Clinical Research Ethics Committee. Questionnaires and informed consent forms were prepared. Data were collected between June 2015 and January 2016. Medical students studying at universities in various provinces of Turkey constituted the target population of the study. Participants were excluded from the study if they had chronic diseases, were younger than 18 years of age, had known chronic and genetic diseases, had deceased parents, had deformities or diseases that prevented height measurement in their parents or themselves, or if they or their parents did not consent to height measurement and the use of their data for the study. The height measurements of both the participants and their parents were performed by fellows and residents working at Marmara University Pediatric Endocrinology Clinic, who were trained and experienced in this field, and recorded on the previously prepared data forms. The ADE MZ10020 ultrasonographic height measurement unit (ADE Gmbh&Co., Hamburg-Germany) was used for the measurements. All measurements were performed with the subjects standing without shoes, on a flat surface, with their eyes facing straight ahead and in accordance with the Frankfurt plane, which is assumed to pass parallel to the ground, connecting the jaw joint and the zygomatic orbital bone.

After all data were obtained, MPH was calculated for each participant and height differences between parents were recorded. Whole group means were calculated together with standard deviation (SD) and standard deviation scores (SDS). Possible correlations of subject height with MPH, maternal height and paternal height were analyzed. After the whole group was subjected to correlation analysis, the correlation analysis of different subgroups was performed. These subgroups included short subjects (*i.e.,* height≤1SDS), tall subjects (*i.e.,* height≥1SDS), subjects with tall parents (*i.e.,* both parents' heights >1SDS), subjects where both mother and father are short (*i.e.,* both parents' height<-1 SDS), and finally, subjects where the difference between mother's and father's height is large (*i.e.,* the height difference between parents>2SDS). The correlation of MPH with subject height was analyzed. Finally, different MPH-based models were compared.

2.1. Statistical Analysis

Data were recorded in a previously prepared Excel file. SPSS (SPSS v21, Armonk, NY, US) software was used for statistical analysis. Descriptive analysis was performed to calculate the means, frequencies and minimum-maximum value ranges of the data. Independent Samples T-Test was used to investigate whether there was a difference in means between paired sample groups. Pearson correlation analysis was performed to determine the direction and level of linear relationship between two numerical variables. Different mathematical models that can be used to predict the final height of the child based on MPH were compared using the "general linear models" method.

3. RESULTS

After applying the inclusion and exclusion criteria to the target population, 988 participants (594 girls and 394 boys) were included in the study. In parallel, the data of 988 mothers and 988 fathers were also recorded together with the participant data. The mean height of female students (n=594) was 164.5±6.4 cm, while the mean height and MPH of their mothers and fathers were 161.1±6.3, 173.4±7.3 and 160.6±5.5 cm, respectively.

In male students, the same parameters were 177.7± 7.1, 162.4± 6.5, 174.1± 6.8 and 174.4± 5.5 cm, respectively.

The mean height of 988 mothers who participated in the study was 161.49±6.5 [140-184] cm. The mean height of the participants' fathers (n=988) was 173.45±7.26 [144-198] cm.

When MPH and actual height of the subjects were compared, actual height was 3.8±5.7 cm longer than midparental height in female subjects and 2.69± 6.4 cm longer in male subjects.

According to the results of the correlation analysis between subject height and MPH, maternal height and paternal height, the correlation coefficient for the correlation of subject height with MPH in girls was found to be 0.537 (*i.e.,* r=0.537), while for the correlations with maternal height and paternal height, these coefficients were calculated as r= 0.486 and r= 0.373, respectively (p<0.01) (Fig. **1**, Table **1**).

When similar analyses were performed for male students, the same parameters were r=0.487, r=0.4 and r=0.404, respectively (p<0.01) (Fig. **2**, Table **2**). As a result of the correlation analysis of subject height with MPH, maternal height and paternal height in short girls, the correlation coefficients were calculated as r=0.279, r=0.315 and r=0.089, respectively (p<0.05) (Table **3**).

In short-statured males, the same parameters gave the results of r=0.175, r=0.395 and r=0.114, respectively (p<0.01) (Table **4**).

When similar analyses were performed in tall girls, the correlation coefficient in the correlation analysis of subject height with MPH was calculated as r=0.322, while the coefficients in the correlation analyses with maternal height and paternal

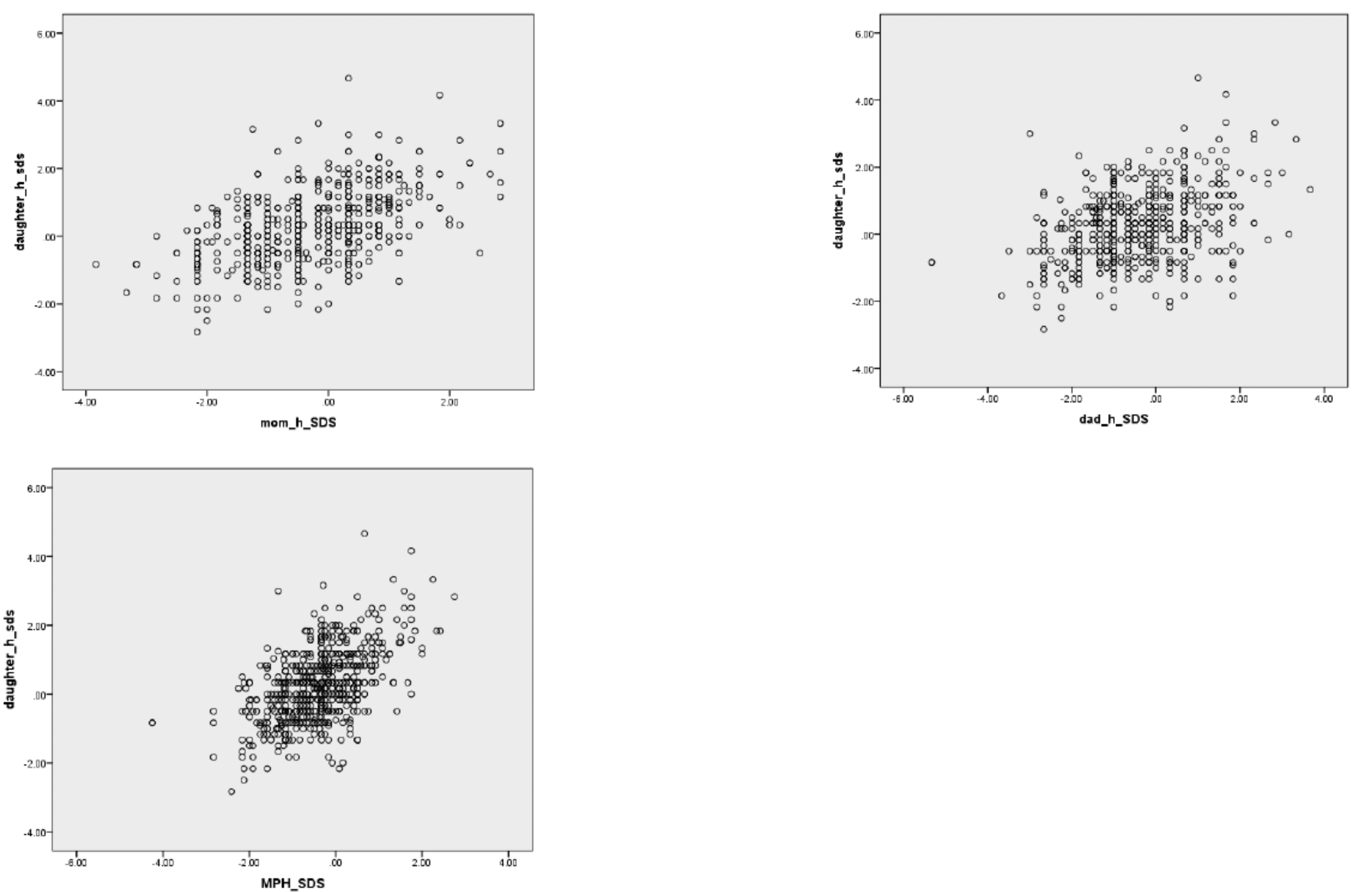

Fig. (1). Correlation graph demonstrating the relation between the standard deviation scores of the heights of the female students and materal, paternal and mid-parental height standard deviation scores.

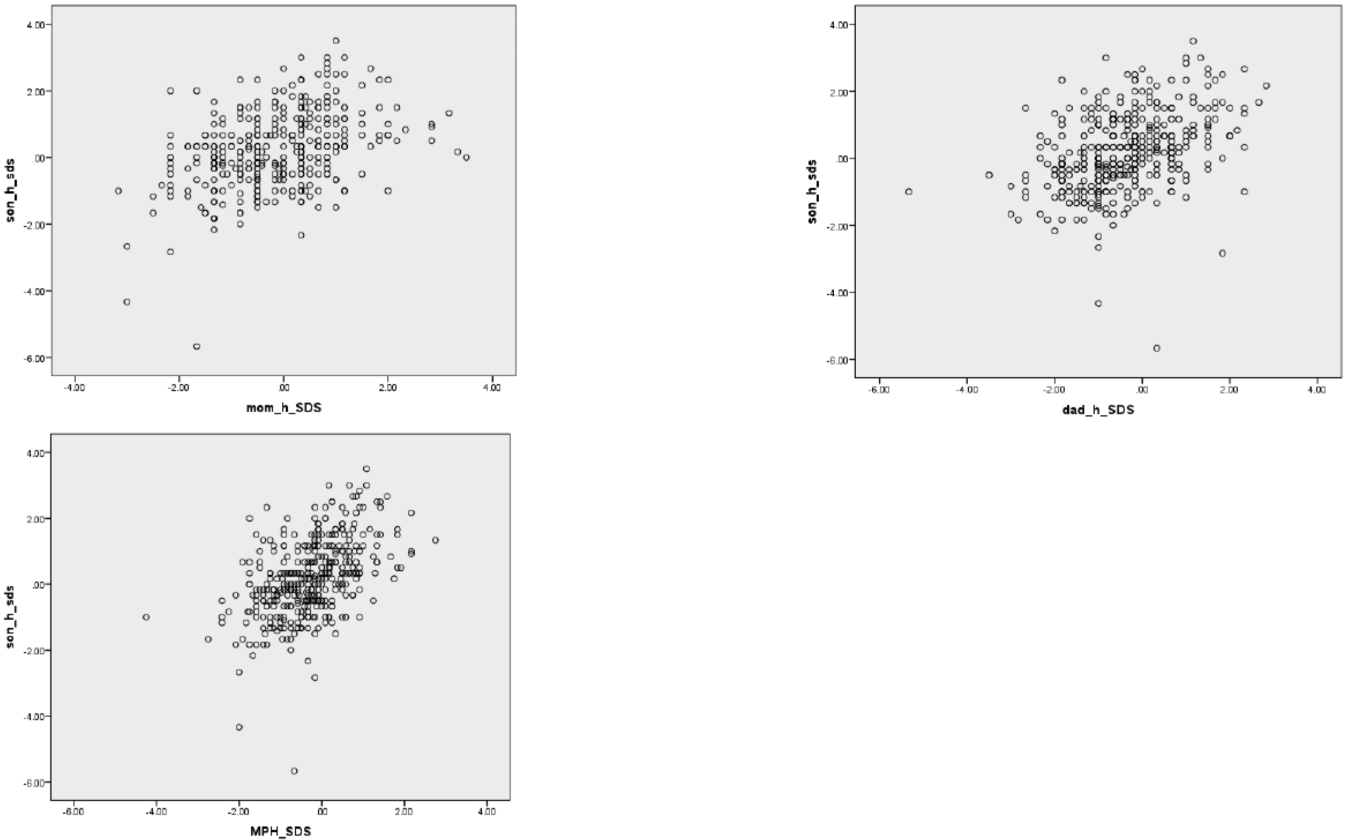

Fig. (2). Correlation graph demonstrating the relation between the standard deviation scores of the heights of the male students and materal, paternal and mid-parental height standard deviation scores.

Table 1. Results of the correlation analysis between maternal height, paternal height and mid-parental height in female participants.

Female		Maternal height SDS	Paternal height SDS	Participant height SDS	Mid-parental height SDS
Maternal height SDS	Pearson Correlation	1	.250**	.486**	.753**
	Sig. (2-tailed)		,000	,000	,000
	N	594	594	594	594
Paternal height SDS	Pearson Correlation	.250**	1	.373**	.826**
	Sig. (2-tailed)	,000		,000	,000
	N	594	594	594	594
Participant height SDS	Pearson Correlation	.486**	.373**	1	.537**
	Sig. (2-tailed)	,000	,000		,000
	N	594	594	594	594
Midparental height SDS	Pearson Correlation	.753**	.826**	.537**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	594	594	594	594

**A 0,01 value is significant (2-tailed)

Table 2. Results of the correlation analysis between maternal height, paternal height and mid-parental height in female participants.

Male		Maternal height SDS	Paternal height SDS	Participant height SDS	Mid-parental height SDS
Maternal height SDS	Pearson Correlation	1	.359**	.400**	.816**
	Sig. (2-tailed)		,000	,000	,000
	N	394	394	394	394
Paternal height SDS	Pearson Correlation	.359**	1	.404**	.833**
	Sig. (2-tailed)	,000		,000	,000
	N	394	394	394	394
Participant height SDS	Pearson Correlation	.400**	.404**	1	.487**
	Sig. (2-tailed)	,000	,000		,000
	N	394	394	394	394
Midparental height SDS	Pearson Correlation	.816**	.833**	.487**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	394	394	394	394

** A 0,01 value is significant (2-tailed)

Table 3. Results of the correlation analysis in short (≤ -1 SDS) female participants.

-		Maternal height	Paternal height	Participant height	Mid-parenatl height
Maternal height	Pearson Correlation	1	-,125	.315*	.544**
	Sig. (2-tailed)		,322	,011	,000
	N	65	65	65	65
Paternal height	Pearson Correlation	-,125	1	,089	.765**
	Sig. (2-tailed)	,322		,483	,000
	N	65	65	65	65
Participant height	Pearson Correlation	.315*	,089	1	.279*
	Sig. (2-tailed)	,011	,483		,024
	N	65	65	65	65
Mid-parental height	Pearson Correlation	.544**	.765**	.279*	1
	Sig. (2-tailed)	,000	,000	,024	
	N	65	65	65	65

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

height were determined as r=0.256 and r=0.245 (p<0.01) (Table **5**).

In the correlation analysis of subject height with MPH, maternal height and paternal height in tall males, r=0.249, r=0.117 and r=0.276 (p<0.01) (Table **6**).

Correlation analyses of subject height with MPH, maternal height and paternal height in female students where both parents were tall revealed the results of r=0.434, r=0.322 and r=0.274 (p<0.01) (Table **7**). In male students where both parents were tall, the same analysis yielded r=0.216, r=-0.460 and r=0.275, respectively (p<0.01) (Table **8**).

Table 4. Results of the correlation analysis in short (≤ -1 SDS) male participants.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	.276*	.395**	.797**
	Sig. (2-tailed)		,024	,001	,000
	N	67	67	67	67
Paternal height	Pearson Correlation	.276*	1	-,114	.800**
	Sig. (2-tailed)	,024		,360	,000
	N	67	67	67	67
Participant height	Pearson Correlation	.395**	-,114	1	,175
	Sig. (2-tailed)	,001	,360		,156
	N	67	67	67	67
Mid-parental height	Pearson Correlation	.797**	.800**	,175	1
	Sig. (2-tailed)	,000	,000	,156	
	N	67	67	67	67

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

Table 5. Results of the correlation analysis in tall (≥ 1 SDS) female participants.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	.193*	.256**	.705**
	Sig. (2-tailed)		,023	,002	,000
	N	138	138	138	138
Paternal height	Pearson Correlation	.193*	1	.245**	.832**
	Sig. (2-tailed)	,023		,004	,000
	N	138	138	138	138
Participant height	Pearson Correlation	.256**	.245**	1	.322**
	Sig. (2-tailed)	,002	,004		,000
	N	138	138	138	138
Mid-parental height	Pearson Correlation	.705**	.832**	.322**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	138	138	138	138

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

In female students where both parents were short, the results were calculated as r=0.271, r=0.204 and r=0.231, respectively (p<0.01) (Table **9**). In the analysis of the correlation of subject height with MPH, maternal height and paternal height in male subjects where both parents were short, the correlation coefficients were r=0.202, r=0.262 and r=0.103, respectively (p<0.01) (Table **10**).

When the correlation of subject height with MPH, maternal height and paternal height was analyzed in the subgroup of female students where the difference between maternal and paternal

Table 6. Results of the correlation analysis in tall (≥ 1 SDS) male participants.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	.343**	,117	.775**
	Sig. (2-tailed)		,000	,247	,000
	N	100	100	100	100
Paternal height	Pearson Correlation	.343**	1	.276**	.860**
	Sig. (2-tailed)	,000		,005	,000
	N	100	100	100	100
Participant height	Pearson Correlation	,117	.276**	1	.249*
	Sig. (2-tailed)	,247	,005		,012
	N	100	100	100	100
Mid-parental height	Pearson Correlation	.775**	.860**	.249*	1
	Sig. (2-tailed)	,000	,000	,012	
	N	100	100	100	100

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

Table 7. Results of the correlation analysis in female participants with tall (≥1 SDS) parents.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	-,069	,322	.637**
	Sig. (2-tailed)		,791	,208	,006
	N	17	17	17	17
Paternal height	Pearson Correlation	-,069	1	,274	.725**
	Sig. (2-tailed)	,791		,287	,001
	N	17	17	17	17
Participant height	Pearson Correlation	,322	,274	1	,434
	Sig. (2-tailed)	,208	,287		,082
	N	17	17	17	17
Mid-parental height	Pearson Correlation	.637**	.725**	,434	1
	Sig. (2-tailed)	,006	,001	,082	
	N	17	17	17	17

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

height was large, r=0.47, r=0.437 and r=0.196 results were obtained (p<0.01) (Table **11**).

In the subgroup of male students where the difference between parents' height was large, the same analysis yielded r=0.417, r=0.479 and r=0.064, respectively (p<0.01) (Table **12**).

In order to determine the model that best predicts the height of the subject based on maternal and paternal height, the models whose formulas are given below were compared using the 'general linear models' method:

Table 8. Results of the correlation analysis in male participants with tall (≥1 SDS) parents.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	-,131	-,460	.770**
	Sig. (2-tailed)		,616	,063	,000
	N	17	17	17	17
Paternal height	Pearson Correlation	-,131	1	,275	.532*
	Sig. (2-tailed)	,616		,285	,028
	N	17	17	17	17
Participant height	Pearson Correlation	-,460	,275	1	-,216
	Sig. (2-tailed)	,063	,285		,405
	N	17	17	17	17
Mid-parental height	Pearson Correlation	.770**	.532*	-,216	1
	Sig. (2-tailed)	,000	,028	,405	
	N	17	17	17	17

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

Table 9. Results of the correlation analysis in female participants with short (≤-1 SDS) parents.

		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	.290**	.204*	.708**
	Sig. (2-tailed)		,004	,048	,000
	N	95	95	95	95
Paternal height	Pearson Correlation	.290**	1	.231*	.881**
	Sig. (2-tailed)	,004		,025	,000
	N	95	95	95	95
Participant height	Pearson Correlation	.204*	.231*	1	.271**
	Sig. (2-tailed)	,048	,025		,008
	N	95	95	95	95
Mid-parental height	Pearson Correlation	.708**	.881**	.271**	1
	Sig. (2-tailed)	,000	,000	,008	
	N	95	95	95	95

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

<u>MODEL 1</u>

Child SDS=(Mother SDS + Father SDS)/2 =MPH SDS

<u>MODEL 2</u>

Child SDS=(Mother SDS + Father SDS)/2 + B= MPH SDS + B

B=0.5 (3 cm)

Child SDS=MPH SDS + 0.5

<u>MODEL 3</u>

Child SDS=[A*(Mother SDS + father SDS)/2] + B = A*MPH_SDS + B

A=0.601

Table 10. Results of the correlation analysis in female participants with short (≤-1 SDS) parents.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	.378**	,262	.759**
	Sig. (2-tailed)		,007	,068	,000
	N	49	49	49	49
Paternal height	Pearson Correlation	.378**	1	,103	.890**
	Sig. (2-tailed)	,007		,481	,000
	N	49	49	49	49
Participant height	Pearson Correlation	,262	,103	1	,202
	Sig. (2-tailed)	,068	,481		,164
	N	49	49	49	49
Mid-parental height	Pearson Correlation	.759**	.890**	,202	1
	Sig. (2-tailed)	,000	,000	,164	
	N	49	49	49	49

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

Table 11. Results of the correlation analysis in female participants with a ≥2SDS difference between the parental heights.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	-.220*	.437**	.472**
	Sig. (2-tailed)		,031	,000	,000
	N	96	96	96	96
Paternal height	Pearson Correlation	-.220*	1	,196	.756**
	Sig. (2-tailed)	,031		,056	,000
	N	96	96	96	96
Participant height	Pearson Correlation	.437**	,196	1	.470**
	Sig. (2-tailed)	,000	,056		,000
	N	96	96	96	96
Mid-parental height	Pearson Correlation	.472**	.756**	.470**	1
	Sig. (2-tailed)	,000	,000	,000	
	N	96	96	96	96

* A 0,05 value is significant (2-tailed)
** A 0,01 value is significant (2-tailed)

B=0.428

Child SDS=0.601*MPH_SDS + 0.428

MODEL 4

Child SDS=A*Mother SDS + B*father SDS + C

MODEL 4a (All Data)

Child SDS=A*Mother SDS + B*father SDS + C

A=0.364; B=0.247; C=0.421

Child SDS=0.364*Mother SDS + 0.247*Father SDS + 0.421

Table 12. Results of the correlation analysis in male participants with a ≥2SDS difference between the parental heights.

-		Maternal height	Paternal height	Participant height	Mid-parental height
Maternal height	Pearson Correlation	1	-,211	.479**	.585**
	Sig. (2-tailed)		,175	,001	,000
	N	43	43	43	43
Paternal height	Pearson Correlation	-,211	1	,064	.669**
	Sig. (2-tailed)	,175		,684	,000
	N	43	43	43	43
Participant height	Pearson Correlation	.479**	,064	1	.417**
	Sig. (2-tailed)	,001	,684		,005
	N	43	43	43	43
Mid-parental height	Pearson Correlation	.585**	.669**	.417**	1
	Sig. (2-tailed)	,000	,000	,005	
	N	43	43	43	43

** A 0,01 value is significant (2-tailed)

<u>MODEL 4b (Female)</u>

Child SDS=A*Mother SDS + B*father SDS + C

A = 0.405; B = 0.223; C = 0.478

Child SDS=0.405*Mother SDS + 0.223*Father SDS + 0.405

<u>MODEL 4c (Male)</u>

Child SDS=A*Mother SDS + B*father SDS + C

A = 0.308; B = 0.301; C = 0.349

Child SDS= 0.308*Mother SDS + 0.301*Father SDS + 0.349

<u>MODEL 5</u>

cChild SDS=[(Mother SDS + father SDS)/2]*r(P,O)*$[(2/(1+ r(P,P))]^{1/2}$ =[MPH_SDS]*r(P,O)*$[(2/(1+ r(P,P))]^{1/2}$

Error SD = $[1-r(P,O)^2]^{(1/2}$

<u>MODEL 6</u>

cChild SDS=[(Mother SDS + father SDS)/2]*r(P,O)*$[(2/(1+ r(P,P))]^{1/2}$ +X

Error SD = $[1-r(P,O)^2]^{1/2}$

X = 0.47 (2.82 cm)

cChild SDS=0.64*MPH_SDS + 0.47

Error SD = $[1-r(P,O)^2]^{1/2} = [1-0.262]^{1/2} = 0.859$

Among the 8 different models whose formulas are given above, Model 4 was the model that most successfully predicted the effect of parental height on subject height (Table **13**).

4. DISCUSSION

Midparental height is the most frequently used parameter reflecting the effect of genetics on height and is easily applicable in clinical practice [6]. In a study conducted by Hermanussen *et al.* in 2003, it was shown that the height of children with short parents was on average 4-6 cm longer than that calculated by the MPH formula [6]. In a study conducted by Su *et al.* in Taiwan, it was observed that children with short parents were on average 2.33 cm taller than calculated by the MPH formula [7].

In a study conducted in Spain, it was observed that boys were 4.44 cm taller and girls were 6.37 cm taller than calculated by the MPH formula [8]. In a study conducted by Luo *et al.* in 1998, it was found that the MPH formula was inaccurate by approximately 6 cm in children with short parents [9]. A study conducted by Wright *et al.* in 1999 concluded that the MPH formula is more reliable for children with normal height limits, while it is not reliable for children with short parents [10].

In their study reported in 2018, Atluri *et al.* evaluated the accuracy of Tanner's formula for predicting target height (TH) in the Asian Indian population [11]. The study found that Tanner's formula underestimated the final height, with

Table 13. Comparison of different potential models in all participants.

-		Model 1	Model 2	Model 3	Model 4A	Model 4B	Model 4C	Model 5	Model 6
N		988	988	988	**988**	594	394	988	**988**
Mean		0,5621	0,0621	0	**0**	0	0	0,4406	**0,0406**
Std. Deviation		1,00166	1,00166	0,9316	**0,92818**	0,86851	1,00277	0,93228	**0,93228**
Minimum		-5	-5,5	-5,69	**-5,56**	-2,65	-5,6	-5,24	**-5,64**
Maximum		4,33	3,83	3,84	**3,88**	3,83	2,79	4,24	**3,84**
Percentiles	5	-1	-1,5	-1,4522	**-1,4171**	-1,3436	-1,4847	-0,9947	**-1,3947**
	10	-0,6667	-1,1667	-1,1131	**-1,125**	-1,0437	-1,1638	-0,68	**-1,08**
	25	-0,0833	-0,5833	-0,6105	**-0,6202**	-0,5899	-0,6442	-0,1867	**-0,5867**
	50	0,5	0	-0,0429	**-0,0358**	-0,0531	-0,0035	0,4067	**0,0067**
	75	1,1667	0,6667	0,557	**0,5722**	0,543	0,5736	1,0067	**0,6067**
	90	1,8333	1,3333	1,2729	**1,2189**	1,1492	1,35	1,6953	**1,2953**
	95	2,2958	1,7958	1,5223	**1,4951**	1,3962	1,7176	1,9564	**1,5564**

males being 2.34 cm taller and females 1.58 cm taller than predicted. Sons' height correlated best with TH, while daughters' height was more closely linked to maternal height. The study also developed new formulas based on parental height, offering more accurate predictions for both sons and daughters. Overall, Tanner's formula was less reliable for this population.

In 2024, Kim *et al.* aimed to re-evaluate the accuracy of Tanner's formula for predicting TH in Korean adolescents and young adults, and to develop a more reliable formula for the Korean population [12]. The researchers used data from the Korean National Health and Nutrition Examination Survey (2010-2019) and included 2586 participants. They found that Tanner's formula underestimated final adult height by about 4.86 cm for men and 4.81 cm for women. Factors such as higher education were associated with a larger height gap, while a history of chronic illness was linked to a smaller gap, especially in women. The study proposed a new formula based on parental heights, which better predicted children's final height and explained 27.6% and 30.6% of the variance in sons' and daughters' heights, respectively. The new formula is suggested as a more accurate tool for assessing growth in Korean children and adolescents.

In another study reported in 2024, Zeevi *et al.* examined the accuracy of the standard method for predicting a child's final height using sex-adjusted mid-parental height [13]. They found that the standard method explained 36% of height variance, with children being 2.7 cm taller than predicted. By adding corrections for parental age, sex, and regression to the mean, prediction accuracy improved, explaining 40% of the variance and reducing the bias to 0.14 cm. The study proposed a refined method for predicting height and assessing whether a child's height deviation falls within the normal range, helping to identify potential medical concerns.

In our study, when the midparental and actual heights of the subjects were compared, the actual height was found to be 3.8±5.7 cm longer than the MPH in girls and 2.69±6.4 cm longer in boys. These findings, as in the studies mentioned above, indicate that the traditional MPH formula is inadequate in predicting the future height of the child.

The correlation analyses performed in our study revealed that the correlation between height and MPH was stronger in girls than boys. In addition, it was found that the correlation between height and mother's height was more potent in girls than in boys. This finding suggests that the effect of maternal height on the height of girls is more substantial. However, in a study conducted by Rios *et al.* in Spain, the father's height was found to be more effective on the final height of boys [8]. In contrast, no significant relationship was found between the final height of girls and the height of their mother or father.

The subgroup analyses showed that the correlation with maternal height was stronger in short students. This finding indicates that -regardless of gender- the effect of maternal height is more dominant in short stature. A multinational study by Addo *et al.* found that 2-year-old children born to short mothers were 3.2 times more stunted than children born to tall mothers [14]. A large-scale study conducted by Su *et al.* in Taiwan showed that paternal height had a more significant effect againon the height of tall boys, while maternal height had a greater effect on the height of short girls [15]. These findings are consistent with our findings.

In our study, the effects of maternal and paternal height were similar in tall girls, whereas the correlation with paternal height was significantly stronger than the correlation with maternal height in tall boys. In addition, the correlation with maternal height was much stronger in subjects with a height difference between parents of more than 2SDS, regardless of gender. These results call into question the concept of MPH, which assumes that the height of the mother and father has an equal effect on the height of the child. Our study shows that maternal height has a greater effect on child height in short boys and girls, whereas paternal height has a greater effect on child height in tall boys and girls. In addition, in families where the height difference between parents is high, maternal height correlates more strongly with child height.

The model whose formula is given below stood out as the most successful model in the comparison between possible predictive models:

Boy SDS: A x Mother SDS + B x Father SDS + C

A: Mother's coefficient (In this model: 0.364)

B: Father's coefficient (in this model: 0.247)

C: Intercept (0.421 in this model)

The mean height of female subjects was 3.1 cm taller than their mothers, while the mean height of male subjects was 3.4 cm taller than their fathers. This finding may be interpreted as an increase in height in the new generation (the trend of the century) or it may be due to the effect of shortening with age in the parents. When the two studies conducted by Neyzi *et al.* in 1978 and 2008 were compared, it was observed that the average height of 17-year-old girls increased by 2.7 cm and the average height of 17-year-old boys increased by 1.5 cm in a 30-year period [16,17]. In a cross-sectional study conducted by Şimşek *et al.* in 2003, anthropological measurements of 1214 school children aged 7-15 years were compared with those of 867 children in the same school in 1993 [18]. In this 10-year period, an increase of 1.7-5.5 cm in average height was found in boys and 1.8-5.7 cm in girls.

In a study conducted by Loesch *et al.* in Australia, it was observed that girls grew 0.01-1.6 cm and boys grew 0.4-2.1 cm in every 10 years [19].

In our study, the difference between the mean height of male and female students was 12.8 cm and the difference between the mean height of the parents was 12.0 cm. This finding is also consistent with the literature [4,20]. In a study conducted by Deaton, it was observed that males were 12.5 cm taller than females on average in the population aged 20-54 years in India [20]. In a study by Garcia *et al.* covering 10 countries in Europe, the height differences between men and women were found to be 15.1 cm in Denmark, 14 cm in Sweden, 12.5 cm in Austria, 11.7 cm in Belgium, 12.8 cm in Finland, 12.7 cm in Greece, 13 cm in Ireland, 11.1 cm in Italy, 10.6 cm in Spain and 10.4 cm in Portugal according to data collected between 1976 and 1980 [21].

CONCLUSION

Although these results are similar across countries, when applied to different countries and populations, it is seen that the classical and traditional MPH formula is unsuitable for global use in predicting the child's final height based on maternal and paternal height. Although our inter-model comparison highlighted a specific model, this model needs to be validated in larger populations.

AUTHORS' CONTRIBUTIONS

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

DECLARATION OF INTEREST

Authors do not have any conflicts of interest to declare

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This study is unfunded

ETHICAL CONSIDERATIONS

Approval for our study was obtained from Medipol University Non-Interventional Clinical Research Ethics Committee. Informed consent was obtained from all participants.

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