Original Article

# Tanner's Target Height Formula Underestimates Final Height in Asian Indians – A Cross-sectional Observational Study

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## Abstract

**Introduction:** Target height (TH) calculation by Tanner's formula has been shown to be inaccurate in many countries However, there is no published data on the accuracy of TH calculation by Tanner's formula in Indians. Hence, this study was conducted to assess whether Tanner's TH formula is an accurate tool to predict final height in Asian Indian population and to identify new TH formulae or models to better fit Indian population. **Material and Methods:** This is a cross-sectional, questionnaire-based study conducted in a tertiary care hospital from South India. A total of 396 questionnaires were randomly distributed to undergraduate medical students who were instructed beforehand to get their heights and heights of their parents and siblings between the age of 18 to 24 years of age measured by a nearby pediatrician. From 396 questionnaires, data of 481 young adults and their parents were obtained. Target height was calculated by Tanner's formula and compared with attained height. **Results:** The study comprised of 197 males and 284 females. Sons and daughters were 2.34 ± 7.19 cm and 1.58 ± 5.68 cm taller than TH. Son's height had best correlation with TH ($r$ = 0.408), whereas daughter's height had best correlation with maternal height ($r$ = 0.560). Both males (0.263 vs 0.365) and females (0.319 vs 0.560) had relatively weaker correlation with paternal heights than maternal heights. Target height explained 29.7% and 16.7% of variance in daughter's and son's height, respectively. Using the parental heights as variables, multiple regression yielded 50.03 + 0.172 (father's height) +0.510 (mother's height) and 74.09 + 0.236 (father's height) +0.377 (mother's height) as the best models to predict daughter's and son's height, respectively. **Conclusion:** Our study suggests that Tanner's TH formula underestimates final attainable height in Asian Indians.

**Keywords:** Parental heights, Tanner's formula, target height

## Introduction

Height is a polygenic trait influenced by both genetic and environmental factors. In pediatric clinics, target height (TH) calculation is a useful tool to estimate the attainable final height for a child or adolescent. Parental heights have a strong influence on postnatal growth and even has been said to be a more powerful predictor than gene loci identified by genomic methods.[1,2] Target height is calculated as (mother's height + father's height)/2 ± 6.5 cm. It was devised by Tanner in 1970 and called as Tanner's TH formula. It has been commonly used for decades in clinics in the evaluation of children with short or tall stature and in the evaluation of growth-promoting therapies in growth hormone (GH) deficient and non-GH-deficient children with short stature. However, a recent study has shown that Tanner's TH formula underestimates the final height by about 6 cm in Swedish population.[3]

Though universally accepted and still widely used, there are several drawbacks to predicting final height based on Tanner's TH formula. Studies have shown that TH explains only 25% variance in attained height and is quite inaccurate in case of extremes of heights in parents or large differences between parental heights.[4,5] Also, secular trends show a steady increase in the height of children over the past century accounting for the underestimation of the height of future generations. Furthermore, there are large variations in these trends among geographical regions.[6,7] Moreover, application of new TH models derived from one country may not accurately estimate the final height in population from a different country.[8]

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Therefore, there is a need for country-specific models to suit their population.[8,9] Hence, this study was conducted to assess whether Tanner's TH formula is an accurate tool to predict final height in Asian Indian population and to identify new TH formulae or models to better fit Indian population.

## Materials and Methods

This is a cross-sectional, questionnaire-based study conducted in a tertiary care hospital, Vydehi Institute of Medical Sciences and Research Center located in Bengaluru, Karnataka. After obtaining institutional ethics committee clearance, informed consent was taken from all the students participating in the study. A total of 396 questionnaires were randomly distributed to undergraduate medical students after prior intimation of the questions that were to be asked. The students were instructed the previous month to measure their own heights as well as that of their parents and siblings above the age of 18 years from a nearby pediatrician. Information regarding their height, weight, age at menarche (for female subjects), birth weight (if known), parental heights, mother's age at menarche (if known), along with siblings' heights, and sisters' ages at menarche were collected by self-reporting from each subject.

From 396 responses, data of 570 young adults (including siblings above 18 years) were obtained. Young adults are referred to as 'children' from here after. Seventy-one children were excluded due to inadequate filling of the questionnaire ($n$ = 53), being younger than 18 years of age ($n$ = 12), and having a history of having taken growth supplementation ($n$ = 6). Another 18 patients with a height standard deviation (SD) score ≤-3 or either of the parents having a height SD score ≤-3 (most likely to have a pathological cause of short stature) were also excluded from the study. Finally, data of 481 subjects were included for the analysis [Figure 1].

Data were analyzed using SPSS version 21 (IBM, Armonk, NY). Data were represented as mean ± SD or percentages as applicable. Correlation between age of menarche and final adult height was calculated using the Pearson's correlation coefficient. Factors determining the final adult height were analyzed using linear regression models and an attempt was made to derive a model to best predict the final height based on TH or combined parental heights. $P$ value < 0.05 is considered as statistically significant.

## Results

The study comprised of 197 males and 284 females. Age of the subjects ranged from 18 to 24 years. Height and height z-scores of children, parents and TH, difference between parental heights and difference between child's height and TH are summarized in Table 1. The heights of the sons and daughters were 175.17 ± 7.58 cm and 160.70 ± 6.40 cm, respectively. Sons were 2.34 ± 7.19 cm taller than TH, whereas daughters were 1.58 ± 5.68 cm taller.

Correlation of child's height and height z-score with that of parental heights and TH is summarized in Table 2. Son's height had best correlation with TH, whereas daughter's height had best correlation with maternal height. Both sons and daughters had relatively weaker correlation with paternal heights than maternal heights.

Target height explained 29.7% of variance in daughter's height and the best model on linear regression to predict daughter's height was 57.09 + 0.651 (TH in cm). Target height explained 16.7% of variance in son's height and the best model on linear regression to predict son's height was 68.86 + 0.615 (TH in cm).

In regression analysis, combined parental heights explained 34.4% variance in daughter's height and 17.3% variance in son's height. The best model obtained on multiple regression analysis to predict daughter's height was 50.03 + 0.172 (father's height in cm) + 0.510 (mother's height in cm), whereas that for sons was 74.09 + 0.236 (father's height in cm) + 0.377 (mother's height in cm). In the analysis of the total study cohort, parental heights explained 16.2% variation in child's height and the best model obtained on multi regression analysis to predict

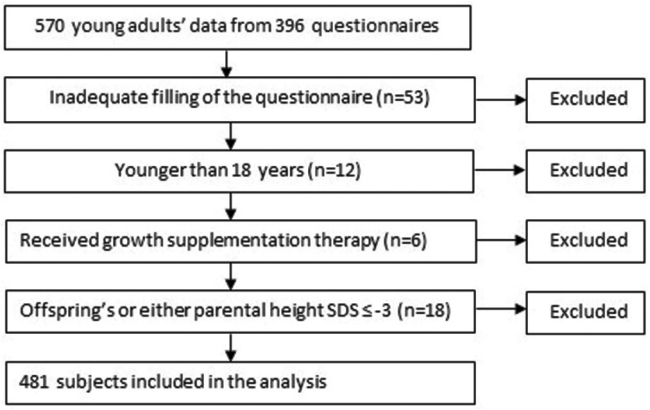


**Figure 1:** CONSORT diagram describing participant selection in the study

**Table 1: Characteristics of the study population**

| | Male ($n$=197) | Female ($n$=284) |
|---|---|---|
| Child's height (cm) | 175.17±7.58 | 160.70±6.40 |
| Father's height (cm) | 172.50±6.48 | 172.07±7.20 |
| Mother's height (cm) | 160.17±6.60 | 159.17±6.44 |
| Midparental height (cm) | 172.84±5.04 | 159.12±5.38 |
| Child's height $Z$-score | 0.27±1.08 | 0.44±1.03 |
| Father's height $Z$-score | −0.11±0.89 | -0.18±0.99 |
| Mother's height $Z$-score | 0.35±1.08 | 0.19±1.06 |
| Midparental height $Z$-score | −0.08±0.70 | 0.19±0.89 |
| Child's height and midparental height difference (cm) | 2.34±7.19 | 1.58±5.68 |
| Mother's height and father's height difference (cm) | 12.33±8.35 | 12.90±8.39 |
| Child's height $Z$-score and midparental height $Z$-score difference | 0.40±1.01 | 0.25±0.92 |
| Mother's height $Z$-score and father's height $Z$-score difference | 0.38±1.02 | 0.36±1.27 |

**Table 2: Correlation of children's height with parental heights and target height**

| | Father's height (cm) | Mother's height (cm) | Target height (cm) |
|---|---|---|---|
| Daughter' height (cm) | 0.319 | 0.560 | 0.548 |
| Son's height (cm) | 0.263 | 0.365 | 0.408 |
| | **Father's height *Z*-score** | **Mother's height *Z*-score** | **Target height *Z*-score** |
| Daughter's height *Z*-score | 0.309 | 0.560 | 0.547 |
| Son's height *Z*-score | 0.261 | 0.356 | 0.409 |

child's height was 45.77 + 0.213 cm (father's height in cm) + 0.528 (mother's height in cm).

## Discussion

We report higher final heights in our study cohort than that expected from Tanner's TH formula. Higher attained height than expected from TH in our study is likely due to secular trend of height increase. Many studies have proven the secular trend in height from generation to generation. A study from Turkey reported higher attained heights than TH in both males (3.8 ± 5.7 cm) and females (2.7 ± 6.4 cm).[4] In Taiwan, Su *et al.*[8] demonstrated a 2.03–2.61 cm rise in height among females as compared to the previous generation and 1.49–3.19 cm rise in males. Similarly, in Sweden, there was a 1.0 cm and 0.7 cm increase in females and males, respectively.[10] Hong Kong Chinese children showed a drastic increase by 4.2–4.8 cm.[10] In most of the studies females showed greater increase in height as compared to males. In a study from Romania, women of 18–24 years in 2010 had a significantly higher height than those in 1998.[11] However, in our study this secular trend was more for boys than girls. A study from Netherlands reported an equal secular increase in height in both girls and boys (4.5 cm) across three generations. Hence, modified TH formulae [(FH + MH)/2 + 11 for boys and (FH + MH)/2 – 2 for girls] have been suggested for Dutch population.[12] Similarly, modified TH formulae [(FH + MH)/2 + 9 for boys and (FH + MH)/2 – 4 for girls] can be suggested from our study for Indian population and could be the simpler modifications for TH formula.

The difference between average son's and daughter's height was 14.67 cm suggesting sex correction factor of 7.33 cm which is slightly higher than 6.5 cm recommended by Tanner. Revised Indian Academy of Pediatrics (IAP) growth charts reported a difference of 15.8 cm between 50$^{th}$ percentile heights of boys and girls aged 18 years.[13] A larger sex correction of 7.2 cm has been previously recommended by Freeman *et al*.[14] However, sex correction is less likely to improve the accuracy of the midparental height formula to predict attainable final height, especially in females.

Correlations of child's height were best with TH in the previous studies.[4,10] Sons in our study followed this pattern, whereas daughters showed better correlation with the maternal height [Table 2]. Bereket *et al.*[4] also demonstrated better correlation of daughter's height with TH than that of sons. In both genders children's heights had better correlations with maternal heights than paternal heights. Better correlations of children's heights with maternal heights than paternal heights in both genders is also reported by Bereket *et al*. However, a previous Indian study published in 1968 did not demonstrate significant gender differences in the correlations between children's height with parental heights.[15]

In the Bereket *et al.* study TH explained only 25% of variance in the children's height, whereas in the Swedish population TH explained 36% and 37% variance in son's and daughter's height, respectively.[4,7] In our study, TH explained only 16.7% and 29.7% variance in son's and daughter's height, respectively. In the regression analysis, the slope was slightly lower in our study for both sons (0.615) and daughters (0.651) when compared to those from Australian data and Swedish data (0.78 for boys and 0.75 for girls).[7] This suggests lower predictability of final height by TH in our study than in Swedish population.[7] In multilinear regression analysis mother's coefficient was higher than father's coefficient in both sons (0.377 vs 0.236) and daughters (0.51 vs 0.172) of our study. Similar observation was also observed in the Bereket *et al.* study (0.364 vs 0.247).[4]

The study was limited by relatively small number of subjects. Inclusion of only medical students from a private medical college and their siblings in the study might have confounded the data since most of them might be from affluent families. Measurement of heights by pediatricians is likely to be accurate and measurement of heights of all members of the family by the same pediatrician nullifies confounding due to inter-observer variation. Though all participants agreed that the heights were measured by pediatricians, this factor could not be verified in all participants. Inaccuracy in reporting by participants might have also confounded the study. Furthermore, the role of other independent predictors of final height such as nutritional status, environmental factors, geographical area, and birth weight was not analyzed. Hence, the findings require further evaluation in larger cohorts across different regions of India and across different socio-economic groups. Although, the new formulae derived from our study may better suit Indian population, these also need further validation in various cohorts from different regions of India.

## Conclusion

Our study suggests that Tanner's TH formula underestimates final attainable height in Asian Indians. However, this observation needs to be confirmed in larger cohorts across different regions of India and across different socio-economic groups.

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## Conflicts of interest
There are no conflicts of interest.

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