

## BoneXpert Adult Height Predictor – User Manual



### Background

The BoneXpert adult height prediction (AHP) method is a new and improved AHP method with better accuracy than the conventional Tanner-Whitehouse-3 (TW3) and Bayley-Pinneau (BP) methods commonly used by paediatric endocrinologists and paediatric radiologists [1-3].

In summary, the BoneXpert AHP is based on the concept of the GP method of remaining growth potential (gp) based on bone age (BA) and chronological age (CA), but makes several improvements including:

- A non-linear dependency of gp on BA–CA and BA
- Inclusion of population height
- Optional inclusion of parental height
- Prediction of the Age of Peak Height Velocity (APHV)
- Visualisation of the most likely growth path in a growth chart and the corresponding height velocity curve

The method is validated on normal, healthy children and on children with untreated idiopathic short stature [2-4].

The BoneXpert AHP method is freely available online at [www.BoneXpert.com/ahp](http://www.BoneXpert.com/ahp) and complements the BoneXpert Server product for automated bone age reading. In combination, the automated bone age measurement and improved AHP method provide the highest possible accuracy for adult height prediction [2-3].

The BoneXpert AHP is intended to be used with GP bone age determined by BoneXpert; however, it can also be used with manual GP bone age, but the uncertainties of the predictions are then greater than indicated, due to the rater variability – the extent of which is unknown.

## The BoneXpert AHP web tool

The tool is available at [www.BoneXpert.com/ahp](http://www.BoneXpert.com/ahp). A screenshot of the tool is shown below. The tool consists of a column of boxes for data entry (1), a column of computed results (2) and a visual representation in form of a growth chart (3). A series of buttons provide options for printing or sharing the result (4).

The tool does not store any patient data or other data.

The result can be saved as a PDF using the “Print as PDF” option built into the web browser, so all the relevant information from an X-ray analysed with BoneXpert can be entered and the PDF used as a final report, and e.g. included as a pdf in a general electronic record system.

The screenshot shows the 'Adult Height Predictor' web tool interface. It features a header with the 'BoneXpert' logo. The main content area is divided into four numbered sections:

- 1. Input fields:** Includes fields for Name, Gender (Male/Female), Ethnicity (Caucasian European North), Bone Age, Age, Height (cm), Father's Height (cm), and Mother's Height (cm). A 'Show BHT' button is at the bottom.
- 2. Computed results:** Displays Bone Age, SDS, APHV, AHP (x-ray), AHP (parents), and AHP (x+p).
- 3. Growth chart:** A line graph showing height (cm) on the y-axis (150-200) versus age (years) on the x-axis (0-20). Multiple curves represent different growth patterns, with a red curve highlighted.
- 4. Action buttons:** Includes icons for printing, saving, and sharing the result.

## Input

The following data can be input. Inputs marked with \* are required. The tool uses dot (.) as decimal point.

*Name*: Any text

*Gender*\*: Male or female.

*Ethnicity*\*: The AHP depends on the ethnicity, and within each ethnicity, it depends on the assumed population height. Nine population groups are available. There are five European Caucasian populations, based on the Zurich Longitudinal study, modelled to different population heights.

For the Asian Chinese and Asian American populations, the tool uses a preliminary AHP model presented at ESPE 2012 [5]. For Hispanic and African-American ethnicities, the Caucasian AHP model is used, which renders it only approximately correct.

The model for APHV (age at peak height velocity) was based on the Zurich Longitudinal study, so the APHV as well as the graphics are not shown for non-Caucasians.

The choice of population also affects the computation of standard deviation scores (SDS).

A secular trend in adult height of 1 cm per generation is assumed.

*Bone Age*\*: Greulich-Pyle bone age entered with decimals (not as years and months!) The tool is intended to be used with automated BoneXpert GP bone age. It will also work with manual GP bone age, but the prediction uncertainties cannot be trusted with manual bone age, since there is no way

to factor in the unknown rater variability. The method accepts a bone age up to 3 years advanced and 3.5 years delayed relative to the chronological age.

**Age\***: Chronological age with decimals, not as years and months. This can be read straight off a hand X-ray analysed with BoneXpert.

**Height\***: Height of the child, in cm

**Father's Height and Mother's Height**: Height of the parents in cm. This is optional, but will increase the accuracy of the prediction.

**Height at Menarche**: This option is only shown for females. It is not mandatory, but will increase the accuracy of the prediction. For a female, this optional input is available. Enter the height in cm at the time when menarche occurred. If you don't have a record of the height right at this time, you can compute it yourself by linear interpolation from measurements taken before and after the menarche.

**BHI**: If the user wishes to use the tool to generate a report, the Bone Health Index from the X-ray analysed with BoneXpert can also be entered by checking the box "Show BHI". This option is currently only available for European Caucasian ethnicities, and it has no effect on AHP.

**BHI:**

**Show BHI**

## Output

The following results are computed. Uncertainties are given as  $\pm 1SD$ , i.e. the true values will be within the indicated range with 68% probability and within  $\pm 2SD$  with 95% probability.

**Bone Age SDS**: The standard deviation score (SDS, or Z-score) of the bone age, relative to children of same age, gender and ethnicity. This output is currently not generated for the Asian Chinese ethnicity. This expresses how many standard deviations the bone age is removed from the average of normal, healthy peers. The standard deviation of bone age is approximately one year at any given age.

**APHV**: Age of Peak Height Velocity. This is the predicted time of the peak of the growth spurt, expressed in chronological age.

Up to four different adult height predictions are given, depending on the input. These are all predictions according to the BoneXpert AHP method. The prediction with the lowest uncertainty, indicated by a green border, should be used, and this is the prediction shown in the growth chart.

**AHP (x-ray)**: Adult height prediction, based on the age, bone age (from the x-ray) and height

**AHP (parental)**: Adult height prediction based solely on the parents' heights and ethnicity. This is similar, but not identical, to the conventional "target height" (which is mid-parental height  $\pm 6.5$  cm), but it is more accurate, because it comprises a drawing towards the population height

**AHP (x+p)**: Adult height prediction based on age, bone age, height and parental height

**AHP (x+m)**: Adult height prediction based on age, bone age, height and height at menarche

A large discrepancy between AHP(x-ray) and AHP(parental) indicates that the child grows differently from what is expected from its parental heritage, i.e. it could be a sign of disorder. The evaluating of

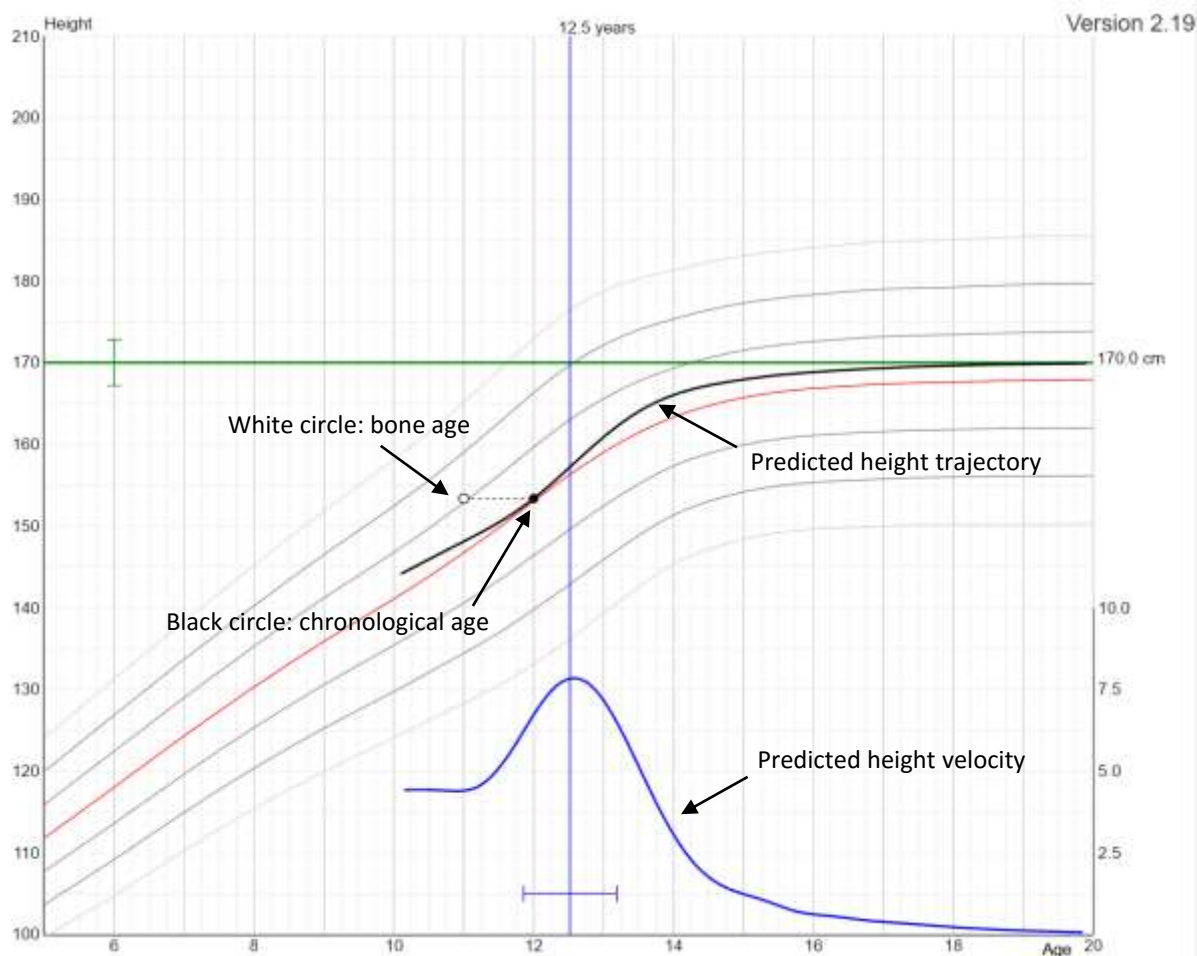
this is the task of a paediatric endocrinologist – the calculator implements the most accurate statistical model, but is not in itself a diagnostic tool.

Below is an example of a girl of age 12.0 with a GP bone age of 11.0. Height and parental height are entered. The most accurate prediction is AHP (x+p), as indicated in green, with an SD of  $\pm 2.8$  cm.

Bone Age:	<input type="text" value="11"/>	Bone Age SDS:	<input type="text" value="-0.73"/>
Age:	<input type="text" value="12"/>	APHV:	<input type="text" value="12.5 &lt;math&gt;\pm&lt;/math&gt; 0.7"/> y
Height:	<input type="text" value="153.4"/> cm	AHP (x-ray):	<input type="text" value="170.4 &lt;math&gt;\pm&lt;/math&gt; 2.9"/> cm
Father's Height:	<input type="text" value="182"/> cm	AHP (parental):	<input type="text" value="167.9 &lt;math&gt;\pm&lt;/math&gt; 4.3"/> cm
Mother's Height:	<input type="text" value="168"/> cm	AHP (x+p):	<input style="border: 1px solid green;" type="text" value="170.0 &lt;math&gt;\pm&lt;/math&gt; 2.8"/> cm
Height at menarch:	<input type="text"/> cm	AHP (x+m):	<input type="text"/> cm

### Growth chart

Below is an example of a growth chart for the girl from the example given in the previous section. The y-axis is height in cm and the x-axis is age in years.



The most accurate adult height prediction, AHP ( $x+p$ ) of 170.0 cm, is plotted and indicated by a green line, and the green whisker indicates the SD = 2.8 cm

The black circle on the growth curve shows the chronological age and the white circle shows the bone age. In this case, the girl's bone age is advanced by 1.0 years relative to her chronological age.

The red curve on the chart indicates the average height of for age in the population, in this example the European Caucasian North. The grey lines indicate the average heights plus minus 1, 2 and 3 standard deviations.

The most likely growth path to adult height is drawn. The corresponding most likely height velocity curve is also plotted; this is the derivative of the growth path. A second y-axis in the right-hand side measures the height velocity in cm per year. The velocity peaks at the APHV, which is marked with a blue line, including a whisker for the 1 SD uncertainty of the APHV prediction. .

### Buttons – print, save URL, background

Three buttons provide additional options.



This prints the page. It is the same as pressing CTRL + P. If you use the built-in “save as PDF” function in your browser, you can save the page as a PDF which may be used as a report.



This updates the URL, storing all information in the address field. Please note: This will also store the patient name, so you might want to leave this field blank.

This is a convenient way of sharing the calculation, e.g. by copying the updated URL into an email.



This will take you to [www.BoneXpert.com/adult-height-predictor](http://www.BoneXpert.com/adult-height-predictor), where some background on the method is provided.

### Offline access, smartphones and tablets

The BoneXpert AHP web tool can be accessed offline once you have accessed it online. Whenever you go online, the newest version will be loaded and saved for offline access.

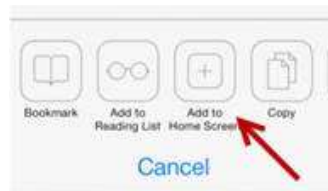
The web page is “responsive” – it will re-scale to fit if you zoom using the browser or if you display the page on a tablet or smartphone.



On Apple devices (iPhone and iPad), the web page can be stored on the home screen similarly to an app, available in offline mode. To do this, navigate to the website in Safari: [www.BoneXpert.com/ahp](http://www.BoneXpert.com/ahp). Then press “Share”:



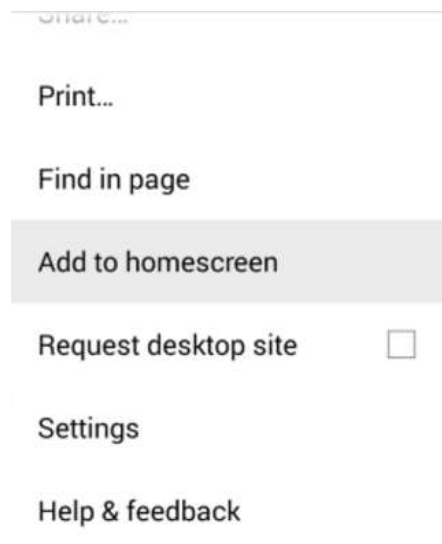
And choose “Add to home screen”:



A new thumbnail of the website named “BX AHP” will appear on your home screen among your apps.



On Android devices, from the standard internet browser or Chrome, press “More” or “...” next to the address field and select “Add to homescreen”.



A new thumbnail of the website named “BX AHP” will appear on your home screen among your apps.

## Validation and background

For a review of the development of AHP methods, the reader is referred to [1].

The BoneXpert AHP model is based on the First Zürich Longitudinal (1ZLS) study of 231 normal children born in 1955[3]. The same study data were subsequently used

1. to derive the model to predict APHV
2. to derive height velocity curves corresponding to different APHV values, and
3. to estimate a standard growth chart, which – like the AHP model – is scaled to the chosen mean population height.

The tool first predicts APHV, which is used to select the most likely height velocity trajectory. This is normalised and integrated to form the most likely height trajectory that ends up exactly in the adult height predicted by the previously developed AHP model.

The AHP method has been validated in the following five studies of non-pathological, untreated children:

- Normal, Caucasian children born in Zurich on average in 1984 [3]
- Normal, Caucasian children born in Denmark 1939-64 [1]
- Normal, Caucasian children born in Johannesburg in 1990 [6]
- Normal Caucasian children born in Paris 1953-1958 [4]
- Untreated, idiopathic, short-stature children born in Tübingen on average in 1980 [2]

## References

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- [5] S.-Y. Zhang, T. Tanaka, D. Martin, G. Liu, C.-G. Ma, Y.-S. Han, X.-Z. Shen, and R.-L. Xu, "Poster P2-d2-459: Adult height prediction for Han children based on automated bone age determination," *Horm. Res. Paediatr.*, vol. 78, no. s1, p. 144, 2012.
- [6] D. D. Martin, H. H. Thodberg, and J. Pettifor, "Abstract WG3-94: At last, an adult height prediction model for black children," *Horm. Res. Paediatr.*, vol. 80, no. s1, p. 22, 2013.

Version	Date	Initial	Comments
1	13 May 2016	PBT	Initial version
1.1	19 May 2016	HHT	Minor changes