Growth of Dutch Children

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In this task you get acquainted with the growth charts for native Dutch children and the mathematical terminology that is used in connection with the diagrams. You learn how these diagrams are made, what they mean, and how they are used. You use them to compare your own stature and weight with your peer group.

You will also compute your target height on the basis of parental data and you will check whether you are growing in this direction. For this part of the task you need to know the height of your biological parents. Ask them at the same time whether they still have growth data of your early childhood. Then you can study your own growth chart! This makes the work much more interesting.

Task A. Growth Charts of Native Dutch Children

Many data of 14,507 native Dutch children and 5,759 Turkish and Moroccan children have been collected in the 4th nation-wide growth study of 1997. Important anthropometric variables, which are used to construct growth charts, are:

- height;
- weight;
- head circumference;
- pubertal stage.

In the attachments there are four growth charts from healthy native Dutch children in the age range of 1 to 21 years. These diagrams are drawn together on a single graph sheet, one for boys and one for girls. A family doctor can use this sheet as a screening tool to identify growth problems of a boy or girl by comparing the child's height and weight to those of other children of the same age and gender (i.e., comparing to the reference population data). The growth chart also shows a child's growth pattern over time. The four diagrams are:

- height-for-age;
- weight-for-height (also referred to as weight-for-stature);
- pubertal stage-for-age;
- head circumference-for-age.

Some parts in these diagrams are shaded and there are all kinds of labels, such as TH and P_{10}, that require further explanation. We do this using the growth charts of Dutch girls, but most mathematical notions can be used for any growth diagram.

Height-for-Age

Percentiles and standard deviation scores
It is customary to express height values in terms of *percentiles*. Seven percentile curves have been drawn in the height-for-age diagram; they are labelled $P_{0.6}$, P_2, P_{16}, P_{50}, P_{84}, P_{98}, and $P_{99.4}$. Below the 2nd percentile curve (P_2) is 2% of the population of the same age and gender. You may interpret this in more than one way:

- In a random sample of 1,000 girls of the same age, about 20 children will have a height that is less than the percentile P_2 (at the given age) and 980 girls will be above the percentile curve.

- A child whose height falls on the 2nd percentile will be taller than 20 and shorter than 980 children of the same age and gender.
- If the child's height is below the P_2 curve, then at least 98% children of the same age and gender are taller.

By definition, 50% of the children of a given age and height are taller than the 50th percentile, and 50% of the children of a given age and gender have a height less than the 50th percentile. The percentile P_{50} is also called the *median*. The P_{25} value and P_{75} value you may know under the names *1st quartile* and *3rd quartile*, respectively. You often meet these names in statistical processing of measured data. They are a measure of the dispersion in a statistical distribution.

Exercise 1.

Basketball players are in general very tall. You may wonder whether they are already tall from childhood on? As an example, we study the growth data of the American star player Shaquille O'Neal. His growth data can be found on the website www.shaq.com. We have converted his data into metric units in the table below.

Age(yr)	4	6	8	10	12	16	21	25
Height (cm)	118	131	144	161	178	201	216	216
Weight (kg)	25	37	49	63	87	120	137	141

(a) Put the data of this basketball player in the attached weight-for-age diagram and in the weight-for-height diagram for boys.
(b) What do you learn about the body growth of Shaquille O'Neal from the two growth curves?
(c) If you know your own personal growth data, place them in the attached growth charts and compare your growth with the mean data for Dutch boys and girls.

There are three drawbacks of the use of percentiles in the height-for-age diagrams:

- You cannot use percentiles very well for extremely low or high values.
- Percentiles are not equidistant. For example, the shift from P_{10} to P_{20} (in cm) is much bigger than from P_{20} to P_{30}.
- Percentiles are not suitable for expressing deviations in a growth curve in measure and number.

In order to meet these shortcomings, the World Health Organisation (WHO) decided not to use percentiles anymore as a basis for the curves in a growth chart, but to base them upon *standard deviation scores* (SDS, also called *z*-scores). Herein one uses mathematical notions like *mean value* and *standard deviation* (SD). You can read them off in the height-for-age diagram: for the mean height you may use the percentile P_{50} and the standard deviation is the difference between the percentiles P_{50} and P_{84}. The standard deviation for girls of age 20 is about 6.5 cm (check this in the diagram in the attachment). The *height standard deviation score* (height SDS)

$$\text{height SDS} = \frac{\text{height} - \text{ mean height for age and gender}}{\text{SD for age and gender}}$$

is the deviation of height, expressed in the number of standard deviations that the height differs from the mean value for the population.

An example: A 15-year-old Dutch girl who is 150 cm in height is very short for her age (mean height at this age is 167.1 cm with standard deviation 6.6 cm). In the height-for-age diagram you can read off that her height is under $P_{0.6}$. Her height SDS is:

$$\text{height SDS} = \frac{150.0 - 167.1}{6.6} = -2.59$$

We say that the height of the girl is 2.59 SD below the mean value for her age.

One considers as "normal range" for height growth the range between –2 and 2 SD (i.e., between P_2 and P_{98}). This region is shaded in the attached growth charts. These diagrams also contain curves at –2.5 SDS ($P_{0.6}$) and +2.5 SDS ($P_{99.4}$). The reason is that the Dutch paediatric organisation has reached the consensus that a family doctor should always refer a child to a paediatrician for further medical examination if the child has a height that is less than –2.5 SDS. A height greater than +2.5 SDS is no immediate cause for referring to a specialist.

Exercise 2.

(a) What is your present height and height SDS? Is your height in the normal range?
(b) What minimal height should you have reached at the age of 15 so that you are not referred to a paediatrician?
(c) What is the present height SDS of Shaquille O'Neal according to Dutch standards?
What height SDS does Shaquille O'Neal have at present according to US standards? (From the NHANES-III growth study, non-Hispanic black: mean final stature 176.5 cm, standard deviation 7.6 cm.)

Height expectation: target height and target range
On the right-hand side of the height-for-age diagram you see the labels F, M, and TH. They label the height of the biological father (F), the height of the mother (M), and the *target height* (TH). The target height is the height that a child should reach on the basis of its genetic potential. You get a simple formula for the target height by writing it as a sum of three contributions:

- the mean parental height;
- the final height of males and females is different: the contribution is ± ½ × height difference;
- the expected increase in height for the next generation.

Exercise 3.

The increase in the final stature for the next generation is estimated in the 1997 growth study as 4.5 cm. The difference between final stature of males and females you can read off from the attached growth charts. Round down the height difference and show that you get the following formulas:

$$\mathrm{TH}_{\mathrm{boy}} = \frac{\mathrm{HF}+\mathrm{HM}}{2} + 11.0 \qquad \mathrm{TH}_{\mathrm{girl}} = \frac{\mathrm{HF}+\mathrm{HM}}{2} - 2.0$$

where HF and HM denote the height of the biological father and mother, respectively.

Using the mean final stature and the standard deviation of adult men and women (184.0 ± 7.1 and 170.6 ± 6.5 cm, respectively) it is possible to compute the *target height SDS* (TH SDS). The formulas for Dutch children are:

$$\mathrm{TH\,SDS}_{\mathrm{boy}} = \frac{\mathrm{TH}_{\mathrm{boy}} - 184.0}{7.1} \qquad \mathrm{TH\,SDS}_{\mathrm{girl}} = \frac{\mathrm{TH}_{\mathrm{girl}} - 170.6}{6.5}$$

The *target range* is the range around the target height in which healthy children are expected to reach their final stature. Consensus is that the target range is 1.3 SD above or below the target height, which means for Dutch boys about 9.2 cm and for girls 8.5 cm. For practical reasons this values is set to 9.0 cm, for both boys and girls.

<u>An example</u>: A 15-year-old Dutch girl who is 150 cm in height, whose father is 185 cm tall, and whose mother is 175 cm tall, has:

$$\mathrm{TH} = \frac{185.0+170.0}{2} - 2.0 = 175.5\,\mathrm{cm} \qquad \mathrm{TH\,SDS} = \frac{175.5 - 170.6}{6.5} = 0.75$$

The height SDS of this girl has been computed before, viz., –2.59 and this value differs –3.34 (= –2.59 – 0.75) from the TH SDS. The height of this girl is far outside the target range.

Exercise 4.

If you know the height of your biological parents you can compute your target height (TH) and TH SDS. Do this and check whether your present height is within the normal range.

Identifying growth problems

A growth chart is used to compare the body growth of an individual child with a peer group of healthy children. In particular, family doctors and other workers in primary health care use the height SDS and TH SDS to identify growth problems. Consensus is that there is no growth problem if:

- the height SDS is greater than –1.3 ($\approx P_{10}$) <u>and</u>
- the growth curve does not deviate (i.e., no deviation greater than 0.25 SDS per year in three successive measurements, with a time interval of at least six months) <u>and</u>
- the height SDS minus TH SDS ≥ –1.3 (i.e., the height is within the target range)

Exercise 5.

Plot the following data in the attached growth chart of boys (height of father and mother is 185.0 cm and 170 cm, respectively):

Date	Age year+month	Height cm
07-04-1992	1 + 0	79.2
09-03-1993	1 + 11	88.5
01-02-1994	2 + 10	97.9
07-02-1995	3 + 10	105.5
05-04-1997	6 + 0	121.5
06-10-1997	6 + 6	123.9
11-04-1998	7 + 0	126.0
03-10-1998	7 + 6	127.5
09-04-1999	8 + 0	129.1

Do the above data indicate growth problems? Underpin your conclusions.

Weight-for-Height, Weight-for-Age, BMI-for-Age

In the attachments you find gender specific weight-for-stature diagrams. They are used as screening tools to identify children that do not weigh as much as they should for their height, at this moment. This may indicate serious weight problems because of acute malnutrition, wasting, dehydration, genetic disorder, infectious disease, or a combination of such factors. Major drawback in the weight-for-stature diagram is that it does not take age into account; only weight and height are used. Especially puberty should be taken into account. Therefore you see in the weight-for-stature diagram that a distinction is made between weight-for-stature graphs before and after the age of 16 year.

Exercise 6.

Use the attached height-for-age diagram and weight-for-stature diagram for boys.

(a) Estimate the age at which a healthy Dutch boy usually reaches half his early adult weight? Do you recall at what age a boy usually reaches half his final height?
(b) Estimate the standard deviation score for a boy of height 139 cm and weight 35 kg.
(c) A healthy Dutch boy weighs 69 pound. Estimate his age, if you have no further information?

A weight-for-age diagram is used as a screening tool to identify under- or overweight and a lag in body development. Major drawback in the weight-for-age diagram is that it does not take height into account; only weight and age are used. Children who are shorter would be expected to weigh a little less than other children of their ages and still be healthy, just as taller children would be expected to have a higher weight. But this does not manifest itself in the weight-for-age diagram. Therefore, it is normally only used in the first 15 months after birth of children.

There exists a third growth diagram that actually contains all three body parameters (age, height, and weight): the *body mass index* (*BMI*, also called *Quetelet index*). It is defined as weight (in kg) divided by the square of the height (in m) and it is plotted in relation to age. The BMI values of children usually range from 12 to 27 kg/m^2. As for the weight-for-stature diagram, there is the drawback that puberty is not taken into account. Alas, for BMI there are no reference population data known that take into account pubertal phases. BMI-values are sometimes used to identify underweight, but much more often to identify overweight and obesity. The following weight classes are used for adults:

BMI in kg/m^2	Weight class
< 18,5	underweight
18,5 – 24,9	ideal weight
25,0 – 29,9	overweight (pre-obese)
30,0 – 34,9	obese class I
35,0 – 39,9	obese class II
≥ 40	obese class III (life threatening)

By the way, all growth charts that involve weight are much more complicated because the statistical distribution is not symmetric around the median anymore. For example, in the BMI-for-age diagram for girls at the age of 22 year the distance between the median and the +2 SDS-line is twice as large as the distance between the median and the –2 SDS-line.

Exercise 7.

The BMI-for-age diagram has a typical shape; see the attachment.

(a) Describe the shape of a SDS-line in a BMI-for-age diagram.
(b) Estimate from the attached growth charts what percentage of Dutch men and women of age 21 yr. suffers from overweight?
(c) Estimate what percentage of Dutch women of age 21 yr. suffers from underweight? What about Dutch men of this age?
(d) What catches your eye if you look in a BMI-for-age diagram at the local maximum and minimum (also called ‘adiposity rebound’) of various SDS curves?
(e) Can you use your answer in part (d) to think of a method to identify as early as possible during childhood the risk of adult obesity?

The last two types of growth diagrams we discuss only briefly. There are no exercises anymore.

Pubertal Phases

During adolescence, a boy or girl is confronted with many changes, both physical and mental. The English paediatrician Tanner has divided the pubertal development of boys and girls into several phases. By the way, the term ‘puberty’ is only used in relation to physical changes such as the development of sex characteristics. For girls, the main changes are the breast development, the appearance of pubic and axillary hair, and the menarche (first menstrual period). Boys also experience changes in the reproductive system (e.g., growth of the penis and enlargement of testes), the appearance of pubic and body hair, and a voice change.

Head Circumference-for-Age

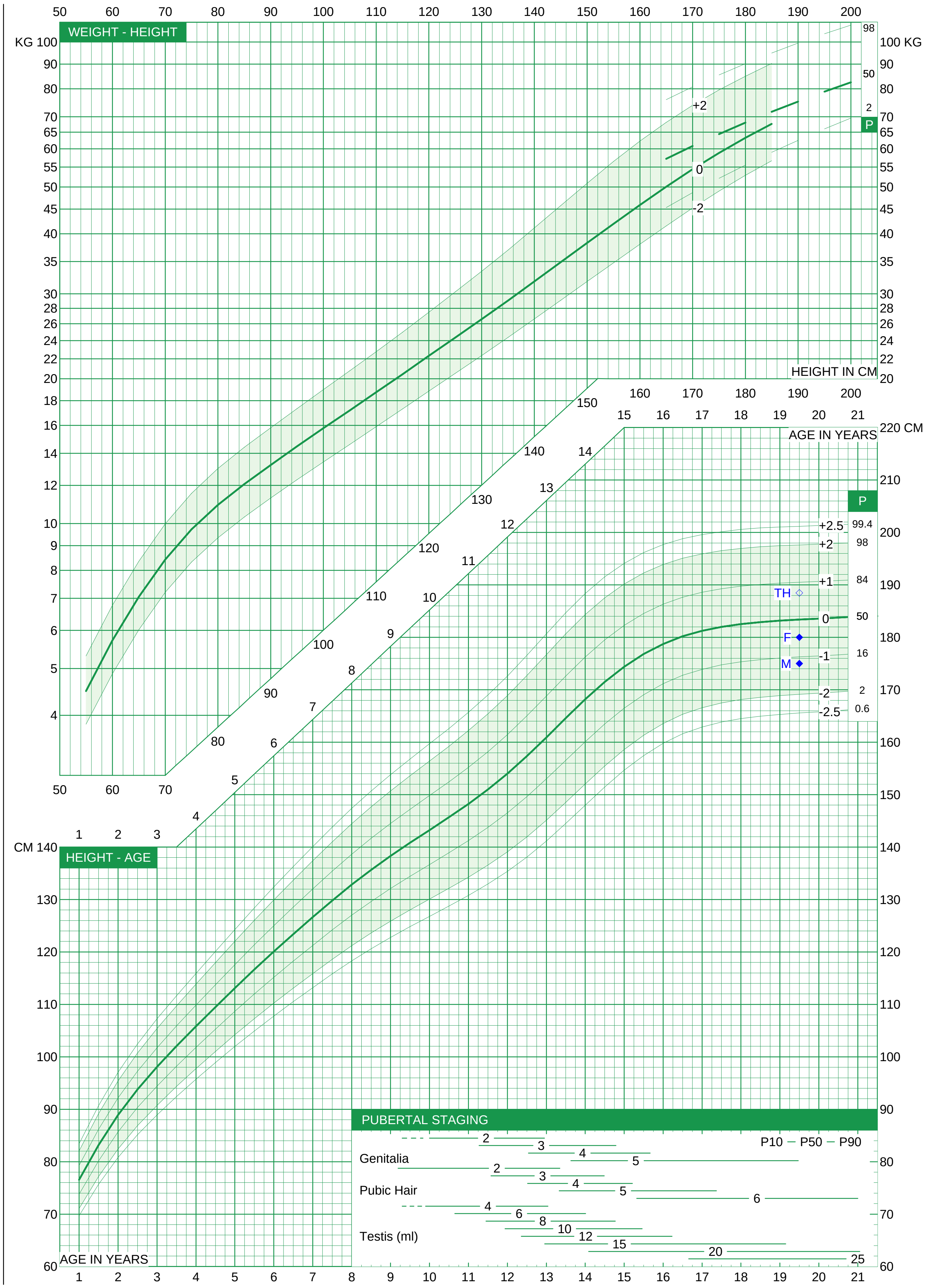
There exists a close relation between the growth of the head and the development of the brains. Because there is also a close relationship between the measured head circumference and the computed volume of the brain, it makes sense to follow the development of the head circumference as a measure for the volume of the head. Underdevelopment may indicate late mental development.

GROEIDIAGRAM 1-21 JAAR JONGENS

Naam MR X		
Geboortedatum 18/5/2000	Reg. nr 1	
Vader (g) 180.00 cm	Moeder (g) 175.00 cm	TH 188.50 cm

< 16 jaar ————

> 16 jaar — — — —



TNO/LUMC, Groei-onderzoek 1997

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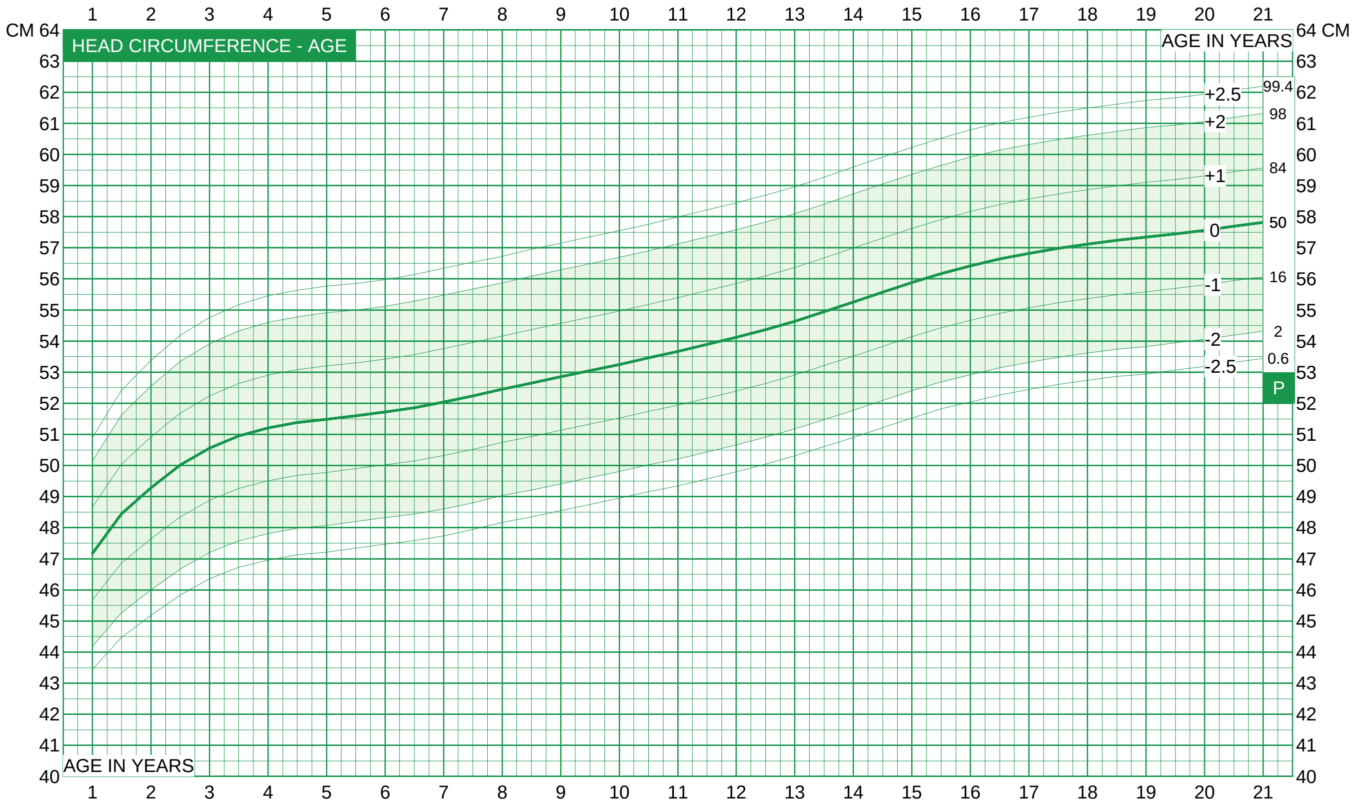


GROEIDIAGRAM 1-21 JAAR MEISJES

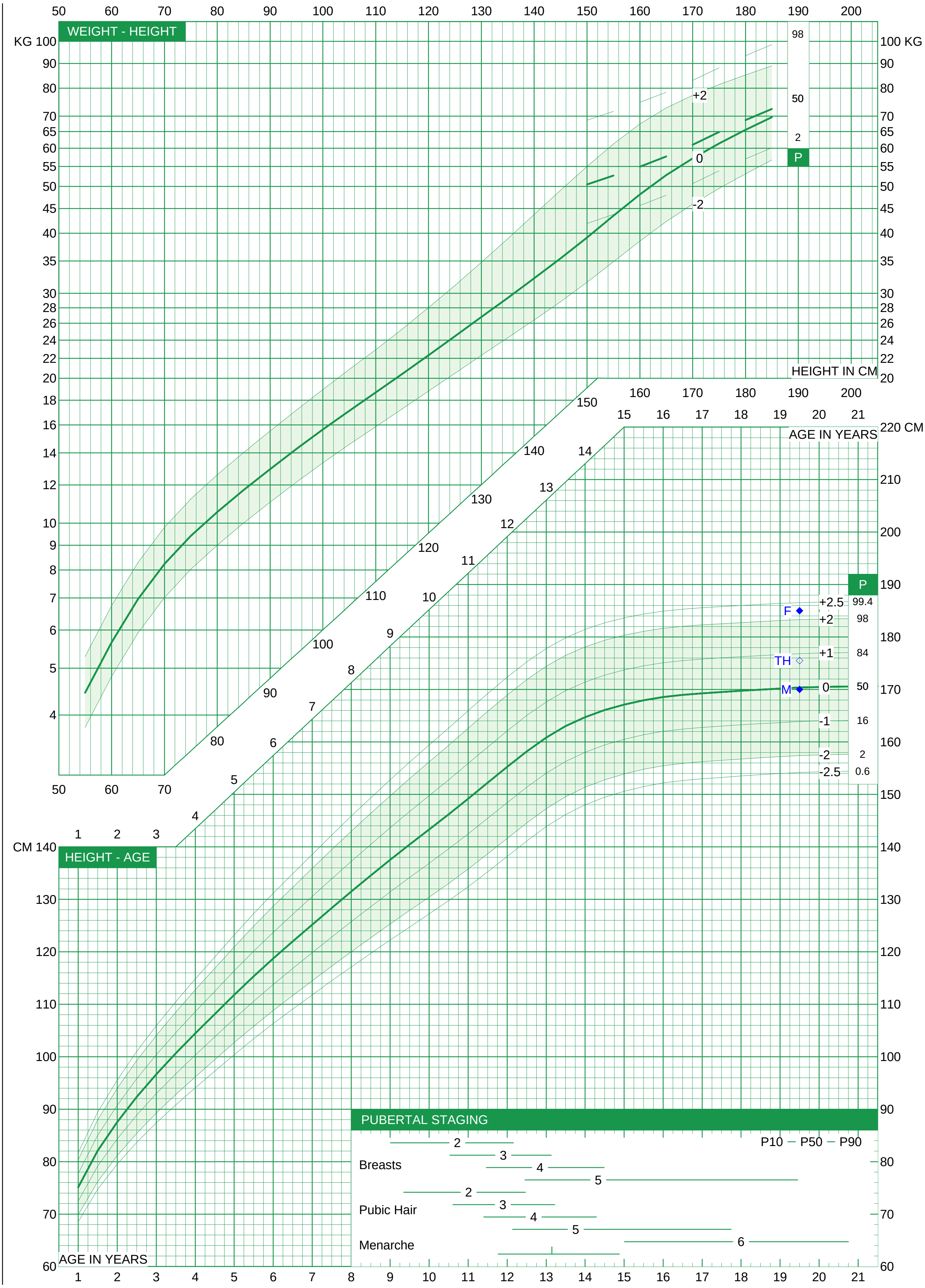
Naam   MRS Y

Geboortedatum   18/5/2000   Reg. nr   2

Vader (g)   185.00 cm   Moeder (g)   170.00 cm   TH   175.50 cm

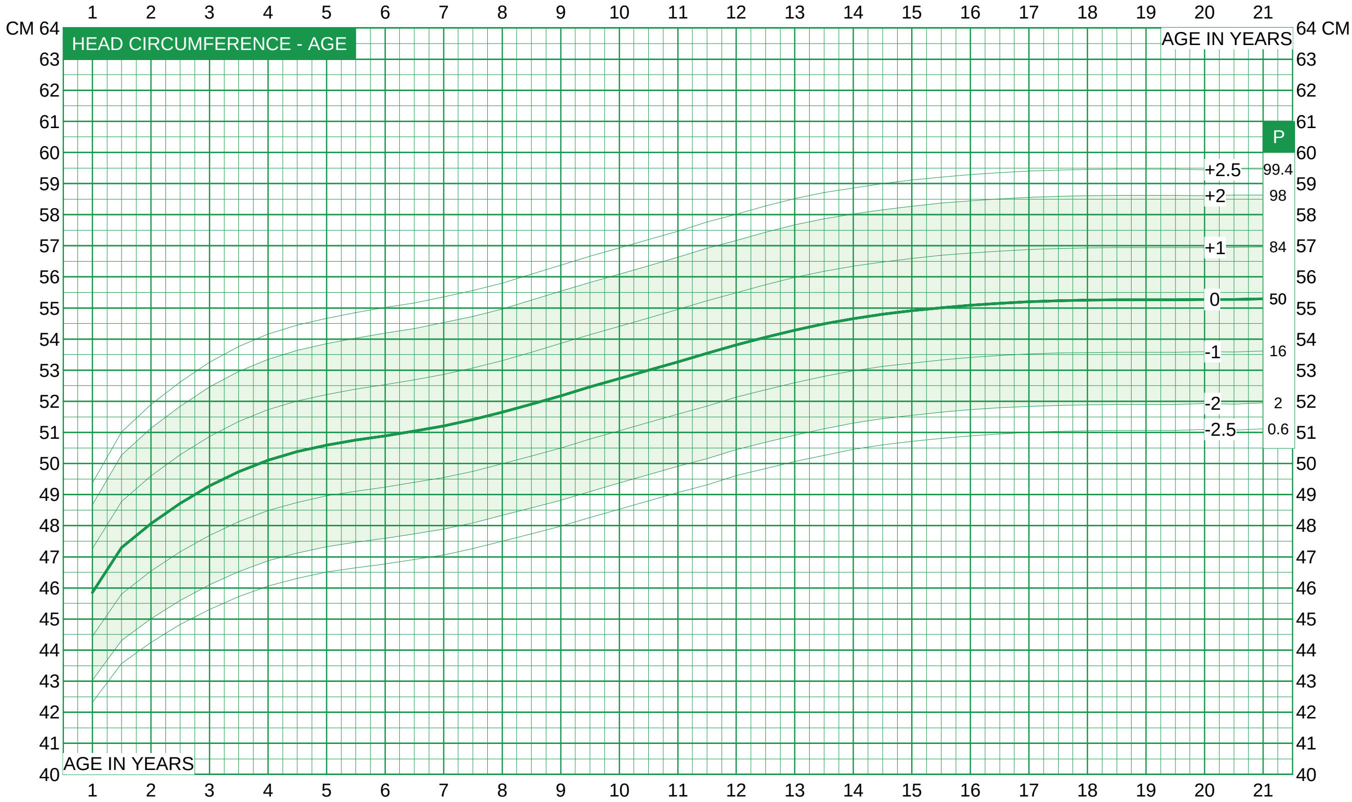
< 16 jaar ————

> 16 jaar — — — —



GROEIDIAGRAM 1-21 JAAR MEISJES

Naam MRS Y		
Geboortedatum 18/5/2000	Reg. nr 2	
Vader (g) 185.00 cm	Moeder (g) 170.00 cm	TH 175.50 cm



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BMI-naar-leeftijd-diagram voor autochtone Nederlandse kinderen

Uit: A.M. Fredriks et al, Body index measurements in 1996-7 compared with 1980, *Arch Dis Child 2000*; 82:107-112.

1997 body mass index (BMI) groeidiagrammen voor Nederlandse kinderen t/m 21 jaar, met -2.5 ($P_{0,6}$), -2 (P_2), -1 (P_{16}), 0 (P_{50}), +1 (P_{84}), +2 (P_{98}) en +2,5 ($P_{99,4}$) SDS-lijnen en bijpassende percentielwaarden.