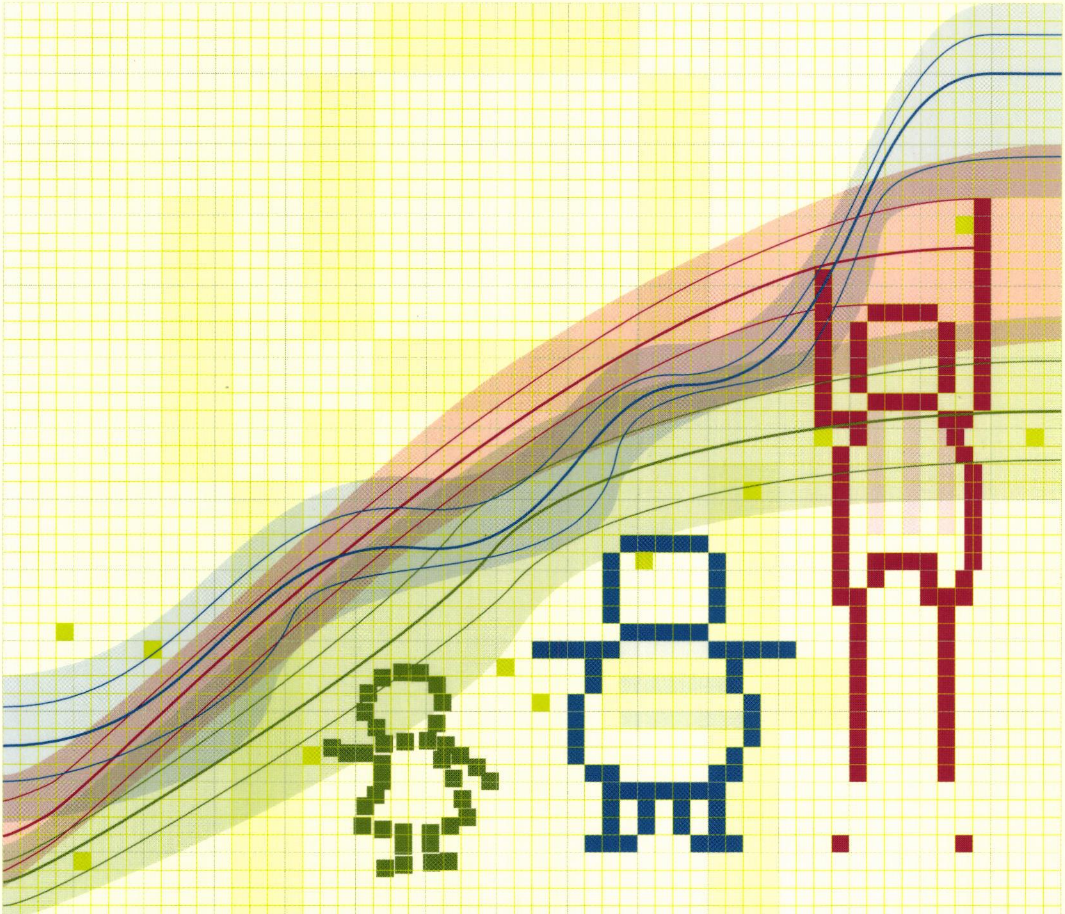
Growth Diagrams

Fourth Dutch Nation-wide Survey

1997



Miranda Fredriks

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Growth Diagrams 1997

Fourth Dutch Nation-wide Survey

Proefschrift

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door

Anke Maria Fredriks

geboren te Apeldoorn
in 1969

Promotiecommissie

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The study in this thesis was performed at the Department of Pediatrics of the Leiden University Medical Center and the Division of Child Health at TNO (the Netherlands Organization for applied scientific research), Leiden, the Netherlands.
This study was carried out in co-operation with Dutch Well Baby Clinics and School Health Care.

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Stellingen

1. De positieve seculaire trend in lengtegroei berust op betere en zuivelrijke voeding, kleinere gezinnen en een afname van het aantal ernstige infectieziekten door een betere hygiëne en een hoge vaccinatiegraad (dit proefschrift).

2. Het plafond van de maximaal haalbare eindlengte is in Nederland nog niet bereikt, maar de lengtetoename per decennium neemt reeds af (dit proefschrift).

3. Regionale lengteverschillen tussen kinderen uit Noord- en Zuid-Nederland kunnen worden verklaard door genetische, socio-economische en levensstijl verschillen en een geringe onderlinge migratie (dit proefschrift).

4. De taille-omtrek is als overgewicht maat minstens zo belangrijk als de BMI, met het voordeel dat de eerstgenoemde gemakkelijker te meten is (dit proefschrift).

5. Bij een kleine lichaamslengte in combinatie met een grote zithoogte/lengte- ratio is er reden om aan hypochondroplasie te denken (dit proefschrift).

6. The timing of puberty may be one early sensor of the effects of genetics and environment, and often a combination of those two. (Endocrine reviews 2003; 24:693)

7. Hoe langer allochtonen in Nederland wonen, des te langer ze worden. (Voeding 1988;4:84-9)

8. Lange mannen zijn minder vaak vrijgezel en zijn populairder bij vrouwen omdat ze goede genen en een welvarende afkomst zouden hebben. (Nature 2000; 403:156)

9. Bij vrouwen zou een taille/heup ratio van 0.7 het perfecte figuur zijn, maar 75% van de variantie voor optimale fysieke aantrekkelijkheid wordt bepaald door BMI, als goede predictor voor gezondheid en voortplanting. (Lancet 1998; 352:548)

10. Wij zien dingen niet zoals ze zijn, maar zoals wij zijn, en dat relativeert.

11. Afslanking van budgetten bij sportbonden staat haaks op de landelijke overheidscampagnes tegen het dikker worden van de jeugd.

12. In volgende generaties zullen de lengte en gewicht verschillen tussen autochtone en allochtone Nederlanders zijn afgenomen, ook zonder inburgeringscursus.

13. Het gevaar bestaat dat we door alle extreem dikkerds de extreem dunnen niet meer zien.

14. Helaas komt het wetenschappelijk belang niet altijd overeen met het maatschappelijk belang, vaak als gevolg van het individuele belang.

Miranda Fredriks 16 juni 2004

Dankwoord

Deze hele studie had niet kunnen plaatsvinden zonder alle duizenden deelnemers, kleine, grote, dikke en dunne, van zowel Nederlandse, Turkse als Marokkaanse afkomst. De kinderen werden allen nauwkeurig gemeten door de artsen en verpleegkundigen van de Ouder en Kind- en Schoolgezondheidszorg. Daarnaast moest nog een tijdrovende vragenlijst ingevuld worden in de toch al drukke spreekuren, heel veel dank hiervoor!

Vervolgens wil ik als eerste mijn promotoren en tegelijk mijn begeleiders bedanken, die in alle tijden van dit promotie onderzoek als een blok achter me hebben gestaan, zowel op wetenschappelijk gebied als op persoonlijk vlak. Jullie vertrouwen en interesse in mij is altijd geweldig geweest.
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Ook wil ik Stef van Buuren bedanken, jij bent een genie in de statistiek en hebt ook nog humor. Een zeldzame combinatie van eigenschappen in een persoon en een kans van 1 op 1.000.000 om daarmee te mogen werken! We hebben vele groeidata bestudeerd, groeidiagrammen geconstrueerd en zitten brainstormen over "wormen" en "meridianen", ideeën die we enthousiast in de praktijk wilden toepassen. Dank voor het vele wat ik van je geleerd heb, voor je uitleg op de "appels en peren wijze" en voor de laagdrempelige samenwerking.
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administratieve kwaliteiten hadden jullie in overvloed, dus het teamwork was top. Daarnaast waren jullie een trouwe steun, de band die in de afgelopen jaren is ontstaan is bijzonder en maakt dat het samen met de andere collegae op TNO elke keer weer een feestje is om bij jullie terug te komen. Mirjam, ook jij bedankt voor al je werk, de afspraken en je interesse, je was een belangrijke schakel tussen Jan Maarten en mij. Irma, de lay-out van het kaft was in goede handen bij jou, veel dank!
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Miranda

From the James M. Tanner lecture (1999):
A short walk in the garden of auxological delights

A first flicker of auxological statement dated already from the Ancient Greeks:
"a division of life into seven year long periods, birth to age seven, 7 to 14 and so on, ending at 70".
Shakespeare began his speech with a version of this classification in his play "As you like it":

All the world's a stage, and all the men and women, merely players:
They have their exits and their entrances;
And one man in his time plays many parts
His acts being seven ages.

Aan mijn ouders

Contents

Chapter 1

Introduction

Introduction

Tanner described growth 'as the mirror of conditions in society' and this largely explains the motivation behind growth studies (1). Auxological data reflect individual body measures, but they also reflect environmental conditions of the population and subpopulations in nowadays multicultural society, allowing comparisons between and within nations (2).

Until 40 years ago, measurements in the Netherlands were mainly carried out in selective subpopulations in society, like conscripts or orphans, and mostly based on non random (often regional) samples. Data derived from burials showed that before 1850 mean stature of Leiden males was 166.7 cm and of females 156.7 cm (3). Conscripts in that time were slightly shorter with a mean height of 165 cm (4). Thereafter, thus in the past 150 years, growth has been studied in a more structured way in the Netherlands (5). A steady increase of mean stature has been observed, reflecting an improving nutritional, hygienic and health status of the population. This so-called positive secular change was interrupted by relatively short periods of a diminished height gain or even height loss in times of agricultural and economic crises and World War I and II, illustrating the important and rapid effect of environmental conditions on growth (6).

In 1955, a first large cross-sectional, nationally representative, growth study was performed in the Netherlands. It was followed by two growth studies with a similar design in 1965 and 1980, showing a positive secular growth change (increase in stature and an earlier sexual maturation). In the 25 years between 1955-1980, final height increased by 6 cm for males (from 176.0 to 182.0 cm) and by 5.3 cm for females (from 163.0 to 168.3 cm), and in that period young Dutch adults became the tallest on earth. (7-9). Most stages of sexual maturation were reached at an earlier age and the median age of menarche shifted to 1.4 months earlier.

In 1992 the first preparations were made to perform a Fourth National Growth Study by a combined project team of TNO Prevention and Health and the Department of Pediatrics of the Leiden University Medical Center, and in 1996 and 1997 all measurements were performed. Three main goals were formulated: 1) to obtain up-to-date references for height and weight as an indicator of health in society; 2) to obtain a variety of anthropometric references as a tool to detect growth disorders; and 3) to provide up-to-date biometric measures for ergonomic purposes, such as material applications.

With respect to the first goal, actual growth references are needed to assess whether any further secular growth change has occurred or whether the maximum biologic stature has been reached. Also for epidemiological purposes, actual growth data allow comparisons with international studies. In contrast to morbidity and mortality, which are negative indicators of health, growth is one of the few positive indicators of youth health. At the time of the preparation of the study, there were indications, through the results of routine health assessments by school doctors and nurses as part of the Dutch Child Health Monitoring System, that height in Dutch children had continued to increase with on average 1-2 cm per decennium over all ages. Besides, more children seemed overweight and more were dieting at the time of the health assessment (10-12).

The question whether any further secular change has occurred is complicated by the fact that, compared with the nineteen eighties, besides several socio-economic changes such as an increasing unemployment, there was also a sharp increase of immigration. An important part of this immigration wave consisted of family members of Turkish and Moroccan guest labourers, in the context of family reunion. For children of Turkish and Moroccan origin no up-to-date references were available and it was uncertain whether a longer stay in the Netherlands was associated with an increasing height (13). It is not unlikely that Turkish and Moroccan are genetically shorter than the Dutch, but the size of the additional effect of their lower average socio-economic conditions is uncertain. Growth data now and in the future can serve as an important indicator for health in these ethnic groups.

With respect to the second goal, the natural consequence of the existence of a secular trend is that with intervals of about 15-20 years new growth references are needed to provide an accurate and sensitive tool, to detect children with growth disorders in youth health care and pediatrics, and for following up the effect of treatment. A timely diagnosis of children with growth disorders improves the quality of care, but on the other hand it is important that as few as possible children without pathological growth disorders are referred for diagnostic procedures (false-positives), so that the children are protected from unnecessary interventions and treatments, and society from unwanted health costs.

With respect to the third goal, up-to-date growth references are needed for numerous ergonomic purposes, such as adaptation of material applications (like furniture, transport etc.) to actual measures. For example children's heights and leglengths are needed for optimal ergonomic chair heights and table heights, recently according to European norms for school furniture, and i.e. head circumference measurements are necessary for close fitting helmets.

Study design of the Fourth Dutch Growth Study

The basic principle of the design was to ensure comparability with the growth references obtained in 1980. A similar cross-sectional study design was used, recording data of infants, children and adolescents at various ages simultaneously during one year. However, by using the knowledge on the general shape of the growth curve and on the expected variation within the population from the first three growth studies, we calculated that less children per age group, and less time points were needed than in the 1980 growth study.

Statural growth is characterized by an extremely rapid phase in the first year, sharply decreasing afterwards to a slowly decreasing stable height velocity between 4-10 years, followed by the pubertal growth spurt, finally resulting in the termination of growth in late adolescence and young adulthood. In general, in the first months a length velocity of ±2.5 cm/month is observed, and over the whole first year of life body length increases by 50% and body weight triples. Growth velocity decreases sharply until two years, and from 4 years of age until 10 years the average rate of growth is rather stable, on average 5-6 cm/year, so that less measurements are needed in that period. Thereafter the rapid growth during puberty starts, and consequently in that period shorter time intervals are needed to obtain an accurate assessment. We adapted the measurement moments also to the standard meeting moments for children in Well Baby Clinics and school heath care. For each age group we needed smaller samples compared to 1980 because the shape of the growth curves is known. The planned sample was 16,188, with at least 226 boys and girls for each age group, based on the objective to detect a height difference of at least 1.8 cm at 18 years of age in comparison with 1980 (with a power of 99%). On the basis of these considerations, the measurement moments varied with age: data were collected in six age groups (two months periods) in year one, four in year two (three months periods), two in year 3 (6 months period), three in the period 3 to 8 years (3 years and 9 months, 5.5 years and 7.5 years) , and two per year between 9 to 21 years for males, and between 9 to17 years for females. For girls the measurement interval was one year from 17 years of age onward. This meant for the personnel in a Well Baby Clinic that each month they had to measure a certain number of boys and girls in the age range 0-2 months, 2-4 months, 4-6 months and so on.

The sample was stratified by province, municipal size, sex and age. Provinces were divided into regions: north (Groningen, Friesland, Drenthe), east (Gelderland, Overijssel, Flevoland), south (Noord Brabant, Zeeland, Limburg), west (Noord- en Zuid Holland, Utrecht) and the large cities (Amsterdam, Rotterdam, Utrecht, The Hague) (table 1). The number of measured children by each Well Baby Clinic or school health care organisation was related to the total number of 0-19 years old children calculated per age per municipal size for each region (National statistics, CBS 1991). For each age group, at least two children were measured in the smallest stratification unit.

Table 1. Measured number of boys and girls, aged 0 to 21 years, per region.

Region	Boys	Girls	Total
North	933	916	1849
East	1546	1501	3047
West	2290	2101	4391
South	1935	1802	3737
Large cities	754	686	1440
Total	7458	7006	14464

Missing region data *n*=45

In 24 Well Baby Clinics and 25 school health care institutions (Child Health Care Services), spread over 36 municipalities in 4 regions, and the 4 large cities, measurements took place by trained health workers. All health workers were visited and similarly instructed and scales were calibrated from the start and during the study. To control for extreme values, health workers were asked for their subjective description of a child's height and weight in the questionnaire. Until 4 years of age children were selected during the regular health assessments by the Well Baby Clinics. Children between 4 and 9 years were measured by school health care institutions during the periodical health examinations. From 9 years onward children received a personal invitation at home based on a stratified sample from the Municipal Registry. Because this resulted in insufficient numbers in the older age groups, we collected additional measurements at high schools, universities, a national Christian (Evangelische Omroep) youth festival, and during medical examinations for joining the army. For 12-17 year olds 25% of the measurements were derived from this additional sample, and between 17-21 years this was 40%. No statistically significant differences were found between the original sample and the additional sample for height SDS, so that we assume that the selection bias is minimal.

The total sample size realized was 14,500 (this means when data on age, gender, and at least one biometric variable were filled in). The sample distribution was found to be similar to figures obtained from national statistics for age, sex, municipal size, family size and child education. Only for girls over 18 years a weighed analysis was needed to correct for differences in geographical region.

A random sample of non-responders (children who refused to show up at the health clinic or refused a measurement) was studied by questionnaires. No significant differences from the study sample were found with respect to the self-reported height and weight compared to the study population. The distribution of demographic variables like educational level of both child and parents, number of children in the family, and working status of the parents did not differ either. Reasons given for non responding were not related to height or weight but included statements such as: no time, no envy or not a personal approach.

To get insight into intra-observer variability, randomly selected health workers performed additional lengths and height measurements. For 0-2 years of age a mean difference of 0.02 cm (n=43) (95% confidence interval –0.10 to 0.14, SD 0.39) was observed. For 2-20 years, a mean difference of -0.06 cm was found (n=159) (95% confidence interval –0.12 to 0.001, SD 0.39). No data on inter-observer variability for height measurements were collected during the study. For testicular volume we refer to chapter 4.

New in this study was the data collection of children of the largest two ethnic groups in the Netherlands, the Turkish and the Moroccans. The sampling method was similar, except that children were measured only in the four large cities, because 56% of the Turkish and 72% of the Moroccans lived in the western region, and most of them in one of the four large cities. The number of measured children was based on the percentages Turkish, Moroccan and Dutch children living in each city. The total sample size was based on the detection of 0.5 cm height difference at 2 years of age and 1 cm at 8 years, between Turkish, respectively Moroccan children, and the Dutch. The realized sample size was n=2,904 for the Turkish children and n=2,868 for the Moroccan children.

Also differently from the previous growth studies, additional biometric measurements were collected of sitting height, waist circumference, and hip circumference, and specific growth reference charts were constructed. In Appendix 1 all included variables were shown in the questionnaires 0 – 4 years and 4 – 20 years.

In this thesis the following questions will be addressed:

- Is there an ongoing positive secular growth change in height between 1980 and 1997?
- Do regional differences in stature still exist?
- Does sexual maturation start earlier than in 1980 and has the duration of the pubertal stages changed?
- Has the weight for height distribution changed over the past 42 years?
- What are the prevalences of overweight and obesity in Dutch youth in 1997?
- What is the correlation between waist circumference, body mass index and height in children, and is waist circumference a useful screening tool in youth health care?
- What are the body dimensions (sitting height, leg length and sitting height/height ratio) in Dutch children, and how effective is the sitting height/height ratio for recognizing growth disorders like Marfan syndrome and hypochondroplasia?

- Are separate growth charts for children of Turkish and Moroccan origin useful or do they hardly differ from the originally Dutch population?
- What are overweight and obesity prevalences in various ethnic groups in the Netherlands?

Outline of this thesis

In **Chapter 2** stature and pubertal development of Dutch youth, derived from four consecutive national growth studies over the period 1955-1997, are compared, to assess the size of the secular growth change. Height differences according to region, educational level of child and parents, and family size were studied and compared to the previous growth studies. Growth references for length, height, weight, head circumference, sexual maturation for age and weight for height are presented for boys and girls of Dutch origin aged 0-21 years.

Chapter 3 reports on age references for sitting height, leg length, sitting height/leg length ratio, and sitting height/height ratio of the reference population. Growth from infancy to final height is a process of a gradual change in body proportions and different parts of the body grow at different times at different speeds. These references are constructed to detect deviations in body proportions in children with growth disorders. This is a vital step in the differential diagnosis, as aberrant body proportions are mainly seen in some specific forms of primary growth disorders, as opposed to secondary disorders or idiopathic short stature.

Chapter 4 is a more detailed report on pubertal development and timing of pubertal stages in comparison to the data obtained in the 1965 and 1980 national growth studies. The development and first appearance of secondary sex characteristics can be regarded as a reflection of the physiologic development in adolescents. The current age limits for the definition of precocious puberty were checked for the Dutch reference population and the influence of height, weight and body mass index on the timing of menarche was studied.

In **Chapter 5** body mass index (Quetelet index) for age reference charts are presented and the distribution of body mass index is compared with the 1980 growth study. Reference lines are compared with the adult cut-off points of 20 kg/m^2, 25 kg/m^2, and 30 kg/m^2 recommended by the World Health Organization/European childhood obesity group to be informed about the prevalences of underweight and overweight in Dutch youth. We also studied the association between body mass index and demographic variables.

Chapter 6 presents the first national waist circumference, hip circumference and waist/hip ratio reference values for Dutch children aged 0-21 years. Waist circumference can serve as an extra tool in the assessment of any obese or overweight child, because a high waist circumference is associated with features of the metabolic syndrome (syndrome X), at least in the adult. However, further studies, particularly long-term longitudinal studies, are needed to assess which reference cut-off lines in childhood and adolescence are to be considered 'risk lines' for syndrome X in adulthood.

As discussed above, in the 1997 study separate growth references were obtained of the largest ethnic groups living in the Netherlands, i.e. the Turkish and Moroccan children. We chose for this strategy in order to be able to study secular change of the ethnic Dutch population, and in order to facilitate optimal growth monitoring for Dutch children as well as children of the two largest ethnic minorities. In **Chapter 7** reference values for height, weight and sexual maturation of children of Turkish origin are given. **Chapter 8** reports on growth references of children of Moroccan origin living in the Netherlands. In both chapters biometric data are compared with demographic variables. **Chapter 9** reveals more detailed data on the prevalences of overweight and obesity observed in the different ethnic groups in the Netherlands. Nowadays an epidemic of obesity exists in many European countries. It is expected to result in increasing health problems in the future and will cause high pressure on health care facilities.

All growth reference curves in the 1997 growth study were constructed with the LMS model described by Cole and Green (14) This model enables the construction of datasets with a Gaussian distribution, so that reference curves based on standard deviations can be made. **Chapter 10** gives the wormplot, a tool that visualizes the differences between two distributions and sustained the choice for optimal values for the appropriate amount of smoothness of the L curve, M curve, and S curve.

Finally, the results and the impact of this growth study, as well as its consequences for future growth studies are discussed in **Chapter 11.** All results and conclusions are summarized in **Chapter 12,** and followed by a summary in Dutch in **Chapter 13**. **Appendix 1** illustrates all included variables in questionnaires for 0-4 and 4-20 years of age. **Appendix 2** includes the complete set of constructed growth diagrams from the Fourth Dutch Nation-wide Survey 1997 (third edition, published in 2004).

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Chapter 2

Continuing positive secular growth change in the Netherlands 1955-1997

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Abstract

Introduction Since 1858, an increase of mean stature has been observed in the Netherlands, reflecting the improving nutritional, hygienic and health status of the population.

Objectives In this study stature, weight, and pubertal development of Dutch youth, derived from four consecutive nation-wide cross-sectional growth studies over the past 42 y, are compared, to assess the size and rate of the secular growth change.

Methods Data on length, height, weight, head circumference, sexual maturation, and demographics of 14,500 boys and girls of Dutch origin in the age range 0-20 y were collected in 1996 and 1997. Growth references for height and weight were constructed with a method that summarizes the distribution by three smooth curves representing skewness (L curve), the median (M curve), and coefficient of variation (S curve). The relationship between height and demographic variables was assessed by multivariate analysis. Reference curves for menarche and secondary sex characteristics were estimated by a generalized additive model using a logit transformation.

Results A positive secular growth change has been present in the past 42 y for children, adolescents and young adults of Dutch origin, although at a slower rate in the last 17 y. Height differences according to region, educational level of child and parents, and family size have remained. In girls, median age at menarche has decreased by 6 mo during the past four decades to 13.15 years.

Conclusions Environmental conditions have been favourable for many decades in the Netherlands, and the positive secular change in height has not yet come to a halt, in contrast to Scandinavian countries. Main contributors to the increase in height may be improved nutrition, child health, hygiene, and a reduction of family size.

Introduction

During the course of the past two centuries in many industrialized countries, a striking increase of mean stature and an earlier sexual maturation, usually called positive secular growth change, has been observed. It is generally assumed that this secular change is elicited by a change of environmental conditions, in particular by removing factors that had blocked full expression of the biological potential, such as infectious diseases, inadequate nutrition, poverty, and suffering (1,2). Growth of a population can therefore be used as a 'mirror of conditions in society'(3). A positive secular change is assumed to reflect improvements in the nutritional, hygienic, and health status of a population (4).

The question arises how long favourable environmental conditions have to be around, before the maximum biological stature is reached in a population. In the Netherlands, a positive secular growth change has been documented since 1858 (preceded by a period of economic growth), interrupted by relatively short periods of a diminished height gain or even height loss during agricultural crises, the world economic crisis in 1930, and World War II (5). Before 1955 secular growth changes were mainly estimated from data on conscripts and other non-random samples from the population. In 1955, 1965, and 1980, however, large cross-sectional nation-wide growth studies were performed, showing that young Dutch adults belonged to the tallest on earth (6-8). In this study we present growth reference data for length/height, weight, head circumference, and secondary sex characteristics from the fourth nation-wide growth study in 1997, using a methodology similar to the previous studies, and compare the results of all four nation-wide growth studies, to assess whether any further secular growth change has occurred.

Methods

Subjects

Data collection for the first nation-wide growth study in the Netherlands took place in 1952 - 1956 and included 16,910 children (6). The second study was performed in the period 1964 - 1966 and included 54,776 children (7). The third study, conducted in 1978 -1980, consisted of 42,000 children (8). In the fourth study, a total of 14,500 children, 7,482 boys and 7,018 girls, were included. They were measured in 1996-1997. In a subgroup of 2,524 boys and 3,028 girls, pubertal stages were also determined. The study was approved by the institutional ethical review board.

Details of the first three studies have been published previously (6-8). Exclusion criteria for the fourth study were similar to those for the previous studies: children with diagnosed growth disorders and those on medication known to interfere with growth were excluded from the sample (*n*=108). Children of non-Dutch parents were also excluded, except if one parent was Dutch and the other West European. In contrast to previous growth studies, infants with a birthweight <2500 g were included for the development of the reference charts, but excluded for assessing the difference in height with the previous growth studies.

The sample was stratified by province, municipal size, sex, and age according to the geographical distribution based on nation-wide demographic data (9). The provinces were clustered into four geographical regions. A fifth region was formed by the cities of Amsterdam, Rotterdam, Utrecht, and The Hague.

The planned sample size (16,188 children, represented by 226 boys and 226 girls for each age group) was almost achieved (*n*=14,500). In the first year of life, infants were divided into six age groups (*n*=2,438), in the second year divided into four age groups (*n*=1,604), and in the third year 918 children were divided into two age groups. At ages 3-8 y, measurements were taken at average ages of 3.9, 5.5 and 7.5 y (*n*=1,677). For 9-20 y of age, the intervals were 0.5 y (*n*=7,863). Until 4 y of age, measurements were mainly performed during the regular periodical health examinations by instructed health professionals in 24 Well Baby Clinics. From the age of 4 y onward, children were measured at 25 offices of Municipal Health Services during regular preventive health assessments (at mean ages 5.5 and 7.5 y) or after receiving a personal invitation based on a stratified sample from the Municipal Register Office (≥ 9 y of age).

The calculation of the planned sample size was based on the aim to detect a 1.8-cm height difference (*p*=0.05) between the 1997 and 1980 studies (with a power of 99%). As in earlier growth studies, difficulties were encountered in collecting a sufficiently large sample of adolescents and young adults. The nonresponders (those who refused to come to the health clinic or refused a measurement) varied from 20 % in 11 years olds to > 60 % in 17 y olds. To detect any selection bias, we approached a randomly sampled subgroup of 230 adolescents and young adults from the nonresponder group. In total, 170 answered a questionnaire, of whom six did not report their height. The self-reported height (*n*=164) was not significantly different from the study population (mean height SDS: -0.10; 95% confidence interval, -0.26 to +0.05; *p*=0.19). No significant differences were found for the distribution of demographic variables either.

To obtain a sufficiently large sample, additional measurements took place at high schools, universities, and a youth festival and during medical examinations for joining the army. In the age range 12-17 y, 25% of the measurements of the study population were derived from this additional sample, and between 17-21 y, 40%. No statistically significant differences were found between the original sample and the additional sample for height SDS.

The distribution of the total sample for age, sex, geographical region, municipal size, family size, and child education was found to be similar to national distributions except for geographical region for girls aged ≥ 18 y (10). For them a weighted correction for geographical region was performed to obtain height references.

Measurements

Length of infants, until two y of age, was measured to the nearest 0.1 cm in the supine position fully extended with their heels in contact with a baseboard. From 2.0 y of age, standing height was measured to the nearest 0.1 cm by using a so-called microtoise, which is an accurate measuring tape, incorporating an indicator, and calibrated in millimetres. Infants up to 15 mo of age were weighed naked, on calibrated baby-scales. Older children were weighed on calibrated mechanical or electronic step-scales, wearing underwear only. Weight was recorded in decigrams for infants, and rounded to the nearest 0.1 kg for older children. The pubertal stages were determined by visual inspection, using the criteria and definitions described by Tanner (11), extended by a sixth stage for pubic hair (7). Testicular volume was estimated by means of a Prader orchidometer. The age at menarche was determined by the status quo method, i.e. each girl was asked whether or not she had had her first period.

A questionnaire, filled in by a health professional, was used to assess demographic variables. Within each region, five categories of municipal size were used, namely <20,000, 20,000-<50,000, 50,000-<100,000, 100,000-<200,000, and ≥200,000 inhabitants. Family size was defined by the number of children in a household (1, 2, 3, and ≥4). The same categories were used for birth rank. As an indicator of socio-economic status the highest completed educational level of the parents was used. The educational level of the child was determined at the time of measurement. If an adolescent of >15 y of age had left any educational system, the highest completed education was recorded.

Statistical analysis

Reference SD curves were estimated by the LMS method (12). This method describes a variable y as a semiparametric regression function of a time dependent variable t, so that the distribution of y changes gradually when plotted against t. The distribution of y is summarized by three natural spline curves, which vary in time: the Box-Cox transformation power that converts y to normality and minimizes the skewness of the dataset (L), the median (M), and the coefficient of variation (S). In the LMS model, the smoothness of L curve, M curve, and S curve is characterized by the number of effective degrees of freedom. The choice of these smoothing parameters for the L, M, and S curves was made by creating local detrended QQ-plots (quantile quantile plots, special plots to compare distributions) (13) of the SDS of the reference sample across 16 age groups. Optimal values of the smoothing factors will produce detrended QQ-plots that are essentially flat. Reference curves for menarche and the stages of secondary sex characteristics were estimated by generalized additive models that use binomial logit link functions to describe the probability of each stage as a smoothing spline function of age (14). Optimal smoothing parameters were determined by means of analysis of deviance.

Differences in mean heights between the samples of 1997, 1980, 1965, and 1955 were computed per age group. Sampling variation in the 1997 study, expressed as a 95% confidence band, was computed by modelling a smoothing spline around mean height. Because the previous studies had larger sample sizes, it was assumed that these had at least equal precision. The association of demographic variables (geographical region, municipal size, family size, birth rank, and educational level for both child and parents) with height SDS was assessed by ANOVA. The variables were taken as a set of categorical independent variables.

Results

For all ages the mean, median and SD were calculated resulting in reference charts for boys and girls, indicating SD lines (0, ± 1, ± 2, and ± 2.5 SD). Length, weight, and head circumference reference charts were made for the age range 0 – 15.0 months. Separate reference charts were made for height and head circumference for age, and weight for height for the age ranges 0 – 4.0 y and 1 – 21.0 y (15, see also Appendix 2).

Height and weight for age

Table 1 summarizes the mean and standard deviation scores for length/height, weight and head circumference for age in 1997. The data for height had a normal distribution for all ages, so that the mean is equal to the median (P_{50}) and to 0 SD. The mean difference between supine length and standing height measurements was +0.4 cm at 24 months of age. The curves for length and height were smoothly joined by maintaining the supine values to 2.0 y and by shifting the values for 2.25 years 0.2 cm upward (7). Weight had a skewed distribution, implying that 0 SD is equal to the median (P_{50}), but not to the mean. Because of the skewed distribution, both -2 SD and +2 SD are given for weight for age.

Table 1. Reference data (0 SD, SD, -2 SD, and +2 SD, when appropriate) for length, height, weight, and head circumference for boys and girls in the age range of 2.0-60.0 wk and 1.0-21.0 y in the 1997 Dutch Growth Study.

Boys							
Age	**Length/Height** (cm) (*n*=7447)			**Weight** (kg) (*n*=7465)		**Head** (cm) (*n*=7037)	
Weeks	**Mean**	**SD**	**-2 SD**	**0 SD**	**+2 SD**	**Mean**	**SD**
2.0	52.9	2.1	3.1	3.9	4.9	36.5	1.4
4.0	54.5	2.2	3.4	4.3	5.4	37.4	1.4
6.0	56.1	2.2	3.7	4.7	5.9	38.3	1.4
8.0	57.6	2.3	4.0	5.1	6.3	39.2	1.4
10.0	59.1	2.3	4.3	5.5	6.8	39.9	1.4
12.0	60.5	2.3	4.6	5.8	7.2	40.6	1.4
14.0	61.8	2.4	4.9	6.2	7.7	41.2	1.4
16.0	63.0	2.4	5.1	6.5	8.1	41.8	1.4
18.0	64.2	2.4	5.4	6.8	8.5	42.3	1.3
20.0	65.2	2.4	5.6	7.1	8.8	42.8	1.4
22.0	66.2	2.5	5.8	7.4	9.2	43.3	1.4
24.0	67.1	2.5	6.0	7.6	9.5	43.7	1.4
26.0	67.9	2.5	6.2	7.9	9.8	44.1	1.4
28.0	68.8	2.5	6.4	8.1	10.1	44.5	1.4
32.0	70.3	2.6	6.8	8.5	10.6	45.1	1.4
36.0	71.6	2.6	7.1	8.9	11.1	45.6	1.4
40.0	72.9	2.6	7.4	9.3	11.6	46.1	1.4
44.0	74.2	2.7	7.6	9.6	12.0	46.5	1.4
48.0	75.4	2.7	7.9	9.9	12.4	46.8	1.5
52.0	76.5	2.8	8.1	10.2	12.7	47.2	1.5
56.0	77.6	2.8	8.3	10.5	13.1	47.4	1.5
60.0	78.7	2.8	8.5	10.7	13.4	47.7	1.5
Years	**Mean**	**SD**	**-2 SD**	**0 SD**	**+2 SD**	**Mean**	**SD**
1.0	76.6	2.8	8.1	10.2	12.8	47.2	1.5
2.0	88.9	3.3	10.4	13.0	16.4	49.3	1.6
3.0	98.1	3.3	12.1	15.2	19.3	50.6	1.7
4.0	105.8	4.0	13.8	17.4	22.4	51.2	1.7
5.0	113.1	4.5	15.5	19.8	25.9	51.5	1.7
6.0	120.1	4.9	17.4	22.4	29.8	51.7	1.7
7.0	126.6	5.4	19.3	25.0	34.0	52.0	1.7
8.0	132.8	5.8	21.2	27.9	38.6	52.5	1.7
9.0	138.3	6.2	23.2	30.8	43.5	52.9	1.7
10.0	143.2	6.6	25.2	33.8	48.6	53.3	1.7
11.0	148.2	7.0	27.4	37.2	54.3	53.7	1.7
12.0	154.0	7.5	30.0	41.5	60.8	54.1	1.7
13.0	160.9	7.9	33.3	46.8	68.3	54.6	1.7
14.0	168.2	8.1	37.6	52.9	76.1	55.3	1.7
15.0	174.4	7.9	42.5	58.8	82.8	55.9	1.7
16.0	178.7	7.6	47.0	63.8	87.7	56.4	1.8
17.0	181.3	7.3	50.7	67.4	91.1	56.8	1.8
18.0	182.6	7.2	53.4	70.1	93.4	57.1	1.8
19.0	183.2	7.2	55.4	72.0	95.1	57.3	1.8
20.0	183.6	7.1	57.2	73.7	96.5	57.6	1.8
21.0	184.0	7.1	58.9	75.3	97.7	57.8	1.8

Table 1 continued

Girls							
Age	**Length/Height** (cm)(n=6992)			**Weight** (kg) (n=6994)		**Head** (cm) (n=6450)	
Weeks	**Mean**	**SD**	**-2 SD**	**0 SD**	**+2 SD**	**Mean**	**SD**
2.0	52.3	2.0	2.9	3.7	4.6	35.8	1.3
4.0	53.6	2.0	3.2	4.1	5.1	36.6	1.3
6.0	55.0	2.1	3.5	4.4	5.5	37.4	1.3
8.0	56.4	2.1	3.8	4.8	5.9	38.2	1.3
10.0	57.7	2.1	4.0	5.1	6.3	38.9	1.3
12.0	59.0	2.2	4.3	5.4	6.8	39.5	1.3
14.0	60.2	2.2	4.6	5.7	7.1	40.1	1.3
16.0	61.4	2.2	4.8	6.0	7.5	40.7	1.3
18.0	62.5	2.3	5.0	6.3	7.9	41.2	1.3
20.0	63.6	2.3	5.3	6.6	8.2	41.7	1.3
22.0	64.6	2.3	5.5	6.9	8.5	42.1	1.3
24.0	65.5	2.3	5.7	7.1	8.8	42.5	1.3
26.0	66.4	2.4	5.9	7.3	9.1	42.9	1.3
28.0	67.2	2.4	6.0	7.7	9.4	43.2	1.3
32.0	68.7	2.4	6.4	8.0	9.9	43.8	1.3
36.0	70.1	2.5	6.7	8.3	10.3	44.3	1.4
40.0	71.4	2.5	7.0	8.7	10.8	44.7	1.4
44.0	72.7	2.6	7.2	9.0	11.2	45.2	1.4
48.0	73.9	2.6	7.4	9.3	11.5	45.5	1.4
52.0	75.1	2.6	7.7	9.5	11.9	45.9	1.4
56.0	76.3	2.7	7.9	9.8	12.2	46.1	1.4
60.0	77.4	2.7	8.1	10.1	12.5	46.4	1.4
Years	**Mean**	**SD**	**-2 SD**	**0 SD**	**+2 SD**	**Mean**	**SD**
1.0	75.1	2.6	7.7	9.6	11.9	45.9	1.4
2.0	87.5	3.2	9.9	12.3	15.5	48.1	1.5
3.0	96.7	3.7	11.7	14.7	18.7	49.3	1.6
4.0	104.5	4.2	13.4	16.9	22.0	50.1	1.6
5.0	111.8	4.6	15.0	19.2	25.5	50.6	1.6
6.0	118.7	5.0	16.8	21.8	29.6	50.9	1.7
7.0	125.2	5.4	18.8	24.7	34.5	51.2	1.6
8.0	131.5	5.6	20.8	27.8	40.1	51.7	1.7
9.0	137.5	6.1	22.8	31.0	46.0	52.2	1.7
10.0	143.3	6.4	24.9	34.5	52.2	52.7	1.7
11.0	149.2	6.7	27.3	38.5	58.8	53.3	1.7
12.0	155.3	6.8	30.4	43.2	65.4	53.8	1.7
13.0	160.8	6.8	34.6	48.3	70.8	54.3	1.7
14.0	164.7	6.7	38.9	52.7	74.7	54.7	1.7
15.0	167.1	6.6	42.4	56.0	77.7	54.9	1.7
16.0	168.6	6.6	45.0	58.4	80.3	55.1	1.7
17.0	169.3	6.5	46.8	60.0	82.3	55.2	1.7
18.0	169.8	6.5	48.1	61.3	83.8	55.3	1.7
19.0	170.2	6.5	49.1	62.3	85.1	55.3	1.7
20.0	170.5	6.5	50.0	63.1	86.1	55.3	1.7
21.0	170.6	6.5	50.8	63.9	87.1	55.3	1.7

Comparison of means heights between the sample according to the exclusion criteria of previous studies (which excluded children with a birthweight <2500 g), and the total sample showed for boys mean height differences of +0.2 cm <1 y of age, +0.1 cm at the age range 1 – 14 y, and no differences from 15 years of age. For girls, mean height differences were +0.2 cm <1 y of age and approximately +0.15 cm over the whole age range ≥ 1 y. In this article, these differences were added to the 1997 reference values for comparison with the previous studies. Thus, height references would slightly increase if the previous criteria had been used.

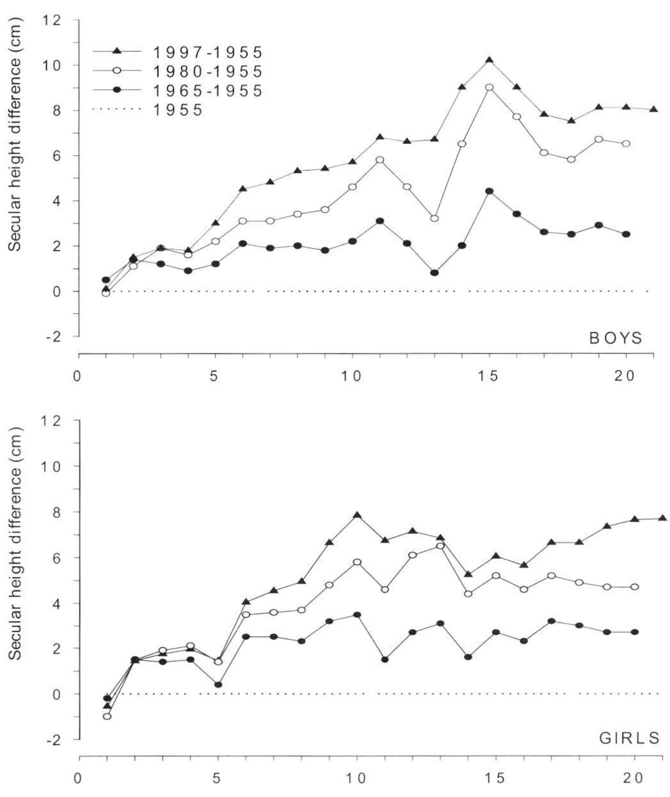

Figure 1. Secular differences in mean height between the 1997, 1980, and 1965 growth studies in comparison to data from the 1955 growth study.

Figure 1 shows the mean final height in 1997 in relation to the three previous national growth studies of 1955, 1965, and 1980. The 1955 study was used as baseline (taking as mean final height at age 21 y 176.0 cm for boys and 163.0 cm for girls). The 95% confidence interval of the median 1997 curve is approximately ± 0.5 cm across all ages. At one year of age, length was similar in all studies. In the age range 1–4 y, the positive secular change was limited to 1-2 cm in comparison to the 1955 study, with little change over the past 32 years. The major part of the secular change occurred in the age range 5–10 y of age in both sexes, which in boys was followed by a further increase up to final height. In 1997, the mean final height at age 21 years for boys and girls amounted to 184.0 cm and 170.6 cm, respectively. During the last 42 years, the mean final height has increased by 8.0 cm for boys and by 7.75 cm for girls.

Figure 2 shows the mean final height in 1965, 1980, and 1997 compared with the 1955 data for both sexes. The mean increase in final height was, respectively, 2.7, 5.7 and 7.9 cm. Thus, the rate of the positive secular change has slowly decreased from 2.7 cm /decade (1955-1965) to 2.0 (1965-1980) and 1.3 cm /decade (1980-1997). A small increase in SD was observed in final height in comparison to 1965 and 1980, but the coefficient of variation remained stable (approximately 3.8%). Thus, mean height increase represented a global shift of the entire height distribution. The difference in mean final height between boys and girls was 13.55 cm (corrected for exclusion criteria) compared to 13.7, 11.7, and 13.0 in the 1980, 1965, and 1955 studies (average difference, 13 cm).

Figure 2. Difference in final height (cm) in the 1965, 1980, and 1997 growth studies relative to the 1955 growth study for boys and girls and their average.

Weight for height

Table 2 contains the actual 0 SD en ± 2 SD values of weight for height in boys and girls. As during adolescence, weight for height is age-dependent; references are presented for two age ranges: <16 y, and ≥ 16 y. In particular, adolescents and young adults had higher weight for height values than in 1980. Detailed comparisons, combined with body mass index references, are reported elsewhere (16).

Table 2. Reference data (-2 SD, 0 SD, and +2 SD) for weight for height in boys and girls in two age ranges in the 1997 Dutch Growth Study.

Height (cm)	**Boys weight (kg)**			**Girls Weight (kg)**		
	-2 SD	**0 SD**	**+2 SD**	**-2 SD**	**0 SD**	**+2 SD**
Age<16.0 y		(*n*=5950)			(*n*=5975)	
50	2.8	3.3	3.9	2.8	3.3	4.0
55	3.8	4.5	5.3	3.8	4.5	5.3
60	4.9	5.7	6.8	4.8	5.7	6.7
65	6.0	7.1	8.4	5.9	7.0	8.3
70	7.2	8.4	10.0	7.0	8.2	9.8
75	8.3	9.7	11.6	8.0	9.4	11.2
80	9.3	10.9	13.0	9.0	10.6	12.6
85	10.3	12.1	14.4	10.0	11.7	14.0
90	11.3	13.2	15.8	11.1	13.0	15.5
95	12.3	14.5	17.3	12.2	14.3	17.2
100	13.4	15.8	19.0	13.4	15.7	18.9
105	14.6	17.2	20.8	14.6	17.1	20.9
110	15.9	18.7	22.8	15.9	18.7	22.9
115	17.3	20.4	25.0	17.3	20.4	25.3
120	18.8	22.3	27.5	18.8	22.3	28.0
125	20.5	24.3	30.3	20.5	24.4	31.2
130	22.3	26.6	33.4	22.3	26.8	34.8
135	24.4	29.1	37.0	24.3	29.4	39.0
140	26.6	31.8	41.1	26.4	32.2	43.7
145	29.1	34.9	45.8	28.8	35.5	49.1
150	31.8	38.3	50.9	31.6	39.2	55.0
155	34.8	41.9	56.5	34.9	43.5	61.3
160	38.0	45.9	62.3	38.5	48.1	67.4
165	41.5	50.1	68.1	42.3	52.8	72.8
170	45.2	54.4	73.9	46.0	57.2	77.3
175	49.1	58.9	79.5	49.6	61.4	81.4
180	52.9	63.3	85.0	53.1	65.5	85.2
185	56.7	67.6	90.3	56.8	69.6	89.0
190	60.5	72.0	95.5			
195	64.3	76.3	100.6			
Age ≥16.0 y		(*n*=1467)			(*n*=990)	
165	45.3	57.2	75.9	41.9	50.5	68.6
170	48.7	60.8	80.7	43.7	52.7	71.6
175	52.1	64.4	85.5	45.7	55.0	74.8
180	55.5	68.1	90.2	47.9	57.7	78.5
185	59.0	71.7	94.9	50.7	61.0	83.0
190	62.5	75.3	99.5	53.9	64.9	88.2
195	66.0	78.9	104.0	57.1	68.7	93.4

Associations of height with demographic variables

The 1965 study demonstrated that mean height for age was related to geographical regions (northern children were taller than southern children), socio-economic status (children with higher SES were taller), and educational levels (children attending special education and lower secondary education were shorter) (5). In 1980, these differences had diminished, but still existed (8). In the 1997 study, mean height was related to geographical region ($p< 0.001$), family size ($p= 0.002$), and educational level of the parents ($p< 0.001$) and the child ($p= 0.002$). No significant association was found with birth rank, and only a slight trend of smaller mean height SDS for increasing birth rank was observed. When taken separately, municipal size was not significantly related to height SDS. However, if municipal size was combined with the other factors, it was significantly associated with height SDS. This effect appeared mainly an effect of the large cities (≥200,000 inhabitants). As this category was already corrected for in geographical region, municipal size was left out of the final set of factors. The magnitude of the effects is shown in figure 3.

Sexual maturation

The P_{10}, P_{50} and P_{90} ages at attaining pubertal stages (genital development (G), pubic hair (PH) and testicular volume for boys, and breast development (B), pubic hair (PH), and menarche (M) for girls) in the 1997 study are shown in table 3. In 1997, girls developed stages B2 and B3 2 months later than in 1980, but 2-3 months earlier than in 1965. However, the median age at B4 and 5 was virtually identical to 1980, both being 6-12 months lower than in 1965. The three months decrease of the mean interval between B2 and B4 since 1980, was not statistically significant (p=0.18, two-sided). The median age at M decreased rapidly between 1955 (13.66 y) and 1965 (13.40 y), followed by a slow decrease to 13.28 and 13.15 years in 1980 and 1997, respectively (1 month/decade). The median age at PH stages 2-5 in 1997 was slightly higher than in 1980, but somewhat lower than in 1965. In boys the age at G2 has slightly increased during the last 32 years, but the median age at G3-G4 has remained similar. The two months decrease of the mean interval between G2 and G4 and PH2 and PH4 since 1980, was not statistically significant (p=0.20, two sided).

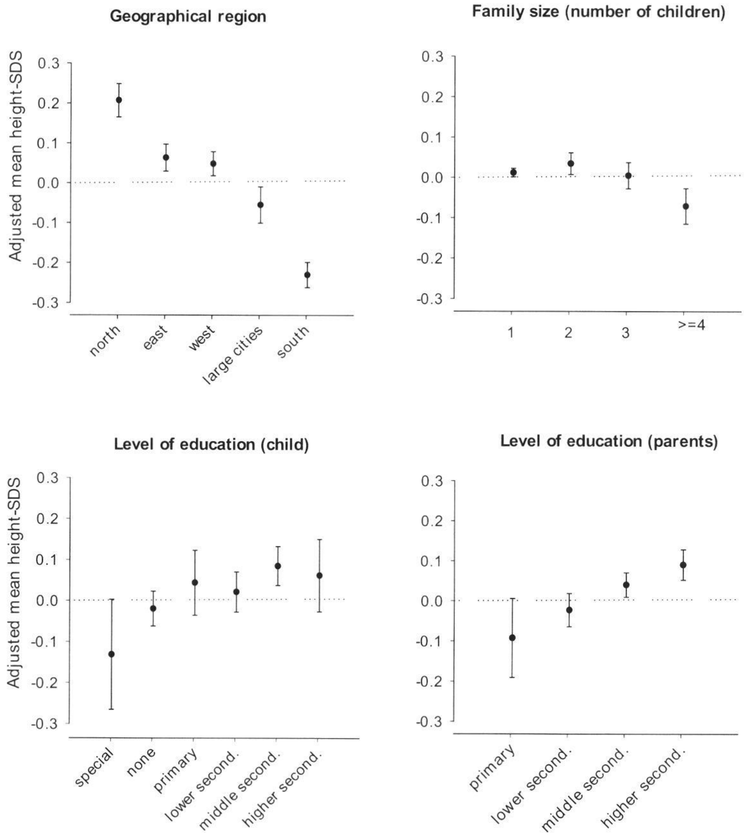

Figure 3. Mean height SDS (with 95% confidence intervals) for geographical region, family size, and level of education of child and parents. Children, <5 years of age, not attending primary education, are assigned to the category none. Shown are the means adjusted for the effects of the other three factors.

Table 3. P_{10}, P_{50} and P_{90} ages (years) of reaching the stages of secondary sex characteristics for boys and girls in the 1997 Dutch Growth Study

		Boys					Girls		
		P_{10}	P_{50}	P_{90}			P_{10}	P_{50}	P_{90}
PH	PH2	9.19	11.73	13.35	PH	PH2	9.35	11.01	12.47
(*n*=2370)	PH3	11.58	12.90	14.49	(*n*=2217)	PH3	10.61	11.89	13.22
	PH4	12.52	13.76	15.21		PH4	11.40	12.68	14.29
	PH5	13.33	14.97	17.37		PH5	12.14	13.76	17.74
	PH6	15.32	18.41	~		PH6	15.01	~	~
G	G2	~	11.45	12.95	B	B2	9.01	10.72	12.16
(*n*=2364)	G3	11.27	12.87	14.49	(*n*=2266)	B3	10.53	11.90	13.13
	G4	12.54	13.93	15.67		B4	11.47	12.84	14.49
	G5	13.63	15.30	19.47		B5	12.46	14.34	19.45
Testic vol(ml)	4	~	11.50	13.04	M	M	11.77	13.15	14.88
(*n*=2524)	8	11.45	12.91	14.77	(*n*=3028)				
	12	12.36	14.01	16.23					
	15	12.96	14.88	19.15					

Discussion

Comparison of the results of the fourth nation-wide growth study with those of the three previous studies shows that during a period of 42 years, the mean height of Dutch children, adolescents, and young adults, in 1980 already among the tallest on earth, has further increased over the past 17 years. At present, the average final height is 184.0 cm for young men and 170.6 cm for young women. Although the rate of secular growth change has gradually diminished, the size of the secular change during the last 17 years (1.3 cm /decade) renders it unlikely that the maximum stature has been reached. The positive shift in the Netherlands is in contrast with the arrest of secular change, reported in Scandinavian countries, where the mean height of conscripts has remained 179.4 cm for the past 17 years (17).

The secular change during the last 42 years varies at different ages, with virtually no change in the first year, very little until 4-5 y, a major change from 5-10 y of age, followed by a stabilization in females and a gradual further rise in males. With respect to the first year of life, the length of female infants in the 1965, 1980, and 1997 studies was even somewhat shorter than in 1955, with in 1997 still a difference of –0.5 cm. The length of male infants at 1 year of age remained very similar over the years, in 1997 being only a few millimetres greater than in 1955. It is unclear why there is no secular change in infancy.

Usually, a positive secular growth change is accompanied by an advance of sexual maturation. In contrast, in Dutch boys the median age at stage G2 tended to increase during the past 30 years, although the mean interval between successive stages tended to decrease. In girls, a progressive shift in median age at menarche slowly decreased during the past four decades, but, the shift during the past 32 years has become small (<1.2 mo/decade). However, stages B2 and B3 tended to occur later than in 1980. Consistent with this maturation shift in both sexes, the final height difference between males and females has remained rather stable, close to 13 cm, a difference similar to that observed in other European and American data (18). If the four growth studies are taken together, the secular change has been almost identical for males and females.

It is generally assumed that improvement of the quantity and quality of food is a most important cause of secular growth change, but it is far from easy to pinpoint the association between the evolution of food consumption and the secular trend (19). In fact, during the past 42 years, the general wealth of the population has increased considerably, and at present virtually all children have easy access to food. The increase in available calories coincided with a decrease in energy lost or expended, mainly because of improved transportation (20). With regard to the quality of food, a clear rise of the consumption of animal proteins and saturated fat was observed between 1936 and 1975 (21), and the present consumption of dairy products in the Netherlands is one of the highest in the world, particularly the use of fermented products (22). Nowadays, the quality of food and a hygienic preparation may be more important to growth than food quantity.

Another major determinant of growth in a population may be the general level of child health. Like most European countries, child health has improved over the past four decades, because of a freely accessible preventive child health system, better hygiene, and a generalized vaccination program (covering 95% of Dutch infants) (23).

The level of education of the parents is significantly correlated with height, in agreement with many other studies in Europe (24). This may be related to differences in lifestyle (smoking, alcohol consumption, consumption of fruit, and vegetables) (25). A cross-national comparison in 10 European countries showed a persistence of the size of education-related height differences in the period 1920-1970, suggesting that inequalities in childhood living conditions will continue to contribute to inequalities in height during the decades to come (24). The lower height of children attending special education may be related to a higher frequency of subclinical congenital disorders. In an earlier study on children with idiopathic short stature without clinical syndromes, we found a clearly elevated number of children undergoing special education (26).

Regional height differences in a small country as the Netherlands, already noted since 1880, are remarkable. For a long time the northern part was predominantly Protestant and the southern part, Roman Catholic. It has been shown that in the 19th century, large-scale education programs were started much earlier in Protestant areas than in Catholic ones (27). Possibly related to this, marital fertility rates and infant mortality (28) decreased in the north from 1870 onward, whereas in the southern provinces this occurred not earlier than 1900. In the southern provinces, the marital fertility remained relatively high until 1970s (29). Until very recently, differences existed in socio-economic status, morbidity, lifestyle, and risk behaviour between the northern and southern regions (25). Differences in nutrition pattern certainly existed in the past (21), but in the last decade no regional differences in nutrient intake have been found in children and adolescents (30). An additional factor may be that the genetic make-up of both regions has remained relatively unchanged, because little migration occurred between northern and southern provinces (31).

A major methodological issue in population based growth studies is whether the procedure sufficiently ensures a representative sample, adequately stratified for the variables known to affect height. In the four consecutive growth studies in the Netherlands, all possible precautions were taken to arrive at a representative study sample, and the methodology has been essentially equal. Still, one problem has been shown to be difficult to resolve, i.e. the high number of nonresponders in adolescents and young adults. In all four growth studies, this problem was faced, and additional samples with less strict stratification were necessary to arrive at a sufficient number of cases. In our most recent study, we tried to assess the differences between the responders and nonresponders through a questionnaire, which indicated that there were no significant differences. However, we could only take a small sample from the total number of nonresponders, and not all individuals responded to the questionnaire, so that there cannot be absolute certainty about a possible selection bias. As to the additional sample, there was an overrepresentation of individuals from the northern provinces in the female adolescents, so that a correction step was needed. We feel confident that the final sample in these age ranges is representative for the population, but it is not unlikely that the fluctuations in the secular change in males and females during the past 42 years are at least partially due to effects of sample selection.

Another major issue is what is meant by the term 'population' of the country, in particular with respect to (second- and third-generation) immigrants. In the four studies described in this article, the population was defined as people who had at least one parent of Dutch origin, so that immigrant children were excluded. One should note, however, that 40-60% of the children in the four largest cities have non-Dutch parents, and that 17% of the whole population are immigrants (32). Although the use of this criterion is needed in order to assess the secular change in the defined population, it will become less and less useful if the growth references are aimed at representing the whole population. Because the height of Turkish and Moroccan children is approximately 1.5 SD lower than that of Dutch children, inclusion of individuals of non-Dutch origin will have a major impact on the growth references and on the course of the secular change in coming decades.

In conclusion, in children, adolescents, and young adults of Dutch origin, the positive secular growth change has still continued, although at a slower rate. In infancy, no secular shift of length was found. Weight for height increased. The onset of sexual maturation in both sexes occurred slightly later than in 1980. Median age at menarche continued to decrease during the past 42 years but at a slow rate. Although the socio-economic conditions have been favourable for a number of decades, the positive secular change still continues.

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Chapter 3

Nation-wide age references for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders.

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Abstract

Introduction To detect whether growth is proportionate or disproportionate, age references for body proportions are needed. For a proper interpretation of Sitting height/Height (SH/H) the cut-off limits for normality must be corrected for height. However the diagnostic value of the SH/H ratio for detecting disproportionate growth disorders has not yet been evaluated.

Objectives To obtain age references for SH, LL and SH/H ratio; to evaluate how SH standard deviation score (SDS), LL SDS, SH/H SDS and SH/LL SDS are related to height SDS; and to study the usefulness of height corrected SH/H cut-off lines to detect Marfan syndrome and hypochondroplasia.

Methods Cross-sectional data on height and sitting height were collected of 14,500 children of Dutch origin in the age range 0-21 years. Reference SD charts were constructed by the LMS method. Correlations were analyzed in 3 age groups. SH/H data from patients with Marfan syndrome and genetically confirmed hypochondroplasia were compared with height-corrected SH/H references.

Results. A positive association was observed between H SDS and SH SDS and LL SDS in all age groups. There was a negative correlation between SH/H SDS and height SDS (r=0.16 and –0.23). In short children with a height SDS below <-2 SDS, a cut-off limit of +2.5 SD leads to a more acceptable percentage of false positive results. In exceptionally tall children, a cut-off limit of -2.2 SDS can be used. Alternatively, a nomogram of SH/H SDS versus H SDS can be helpful. The sensitivity of the height-corrected cut-off lines for hypochondroplasia was 80% and for Marfan syndrome only 30%.

Conclusions. In exceptionally short or tall children, one has to take into consideration the dependency of the SH/H ratio (SDS) on height SDS in the evaluation of body proportions. The sensitivity of the cut-off lines for hypochondroplasia is fair.

Nation-wide age references for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders.

Introduction

In the diagnostic work-up of children with exceptionally short or tall stature, the visual inspection and objective measurement of body proportions can give important clues (1-3). The usual method of judging body proportions of children is to calculate the ratio between sitting height and height (SH/H) or sitting height and leg length (SH/LL) and compare this with age references. Sitting height can also be used as a proxy of statural growth if height cannot be measured, for example because of lower limb deformities.

In short children, most chondrodystrophic syndromes (skeletal dysplasias) are characterized by short limbs. In contrast to achondroplasia, hypochondroplasia can be difficult to diagnose. Hypochondroplasia is an autosomal dominant condition characterized by a disproportionate short stature, with relatively short legs, micromelia, macrocrania and lumbar lordosis, linked to N540K mutations in the FGFR3 gene. Also other conditions, such as Down syndrome and Turner' syndrome can present with abnormal body proportions. On the other hand, some other syndromes associated with short stature present with a relatively short trunk.

In tall children, it is important to diagnose Marfan syndrome, gonadotropin deficiency and Klinefelter syndrome, because of the clinical consequences. Marfan syndrome is an autosomal dominant disorder of connective tissue characterized by a disproportionate tall stature and relatively long legs. In summary, body proportions contain vital diagnostic information in the work-up of growth disorders.

It is generally known that tall children have relatively long legs and vice versa (4,5). Therefore, we conjecture that the interpretation of SH/H ratio should not only be based on age references, but also on height. This would theoretically improve the specificity of the cut-off lines. However, no such conditional references are available. Also about the sensitivity of the usual cut-off lines of normality (+ or - 2 SDS), either corrected for age only or after an additional correction for height, in detecting the most frequent disproportionate growth disorders no information is available.

In this paper we present age references of SH, LL and SH/H ratio for Dutch children, and show their relationship with height. In addition, we compare SH/H of children with known Marfan syndrome and known hypochondroplasia with the new references in order to determine whether the usual cut-off limits in the references charts are appropriate in detecting these disorders.

Methods

Subjects

Cross-sectional data on height and sitting height were collected in the Fourth Dutch Growth Study in 1996 and 1997. A total of 14,500 children, 7,482 boys and 7,018 girls, of Dutch origin in the age range 0-21 years were included. Sitting height was measured in 6,877 boys and 6,202 girls. Children with known growth disorders and those on medication known to interfere with growth were not included in the sample. Details have been described elsewhere (6). The sample was nationally representative. Separately, we collected growth data of children with Marfan syndrome; 4 boys (of 3, 6, 9, and 13 y) and 6 girls (of 8 (n=4), 12, and 16 y). Through the Laboratory of Clinical Genetics and referring physicians, we anonymously gathered data on individuals with DNA-confirmed hypochondroplasia: 7 children (3 boys (of 4, 6, and 12 y) and 4 girls (of 1, 6, 10, and 12 y)), and 3 adults (1 man of 41 y, and 2 women 24 and 43 y old). In addition we gathered data of a family of a girl 10 years of age, with a confirmed HCH mutation in the FGFR3 gene that caused a mild hypochondroplasia. None of these patients had been treated with any relevant medication at time of the measurement.

Measurements

Length of infants, until 2 years of age, was measured to the nearest 0.1 cm in the supine position, fully extended with their heels in contact with a baseboard. Crown-rump length, a measure of trunk length, which is conceptually similar to sitting height in older children, was measured until two years of age while the child was lying in supine position on a measuring table. After the thighs were placed in a vertical plane, the footboard was pulled against the buttocks. From 2 years of age onward, standing height was measured to the nearest 0.1 cm by using a calibrated microtoise. Sitting height was measured by bringing the horizontal bar of the microtoise into the most superior midline of the head while the child was sitting in erect position on a flat stool or box. Arching of the back was avoided as much as possible by applying upward pressure to the mastoid processes while the child breathed deeply and held its breath during the measurement. The difference between crown-rump length and sitting height was on average +0.4 cm at 2 years of age. For the ratio crown-rump length/length and sitting height/height the difference was on average +0.03. Leg length was obtained by subtracting sitting height from height. The difference between length and crown-rump length is a corresponding estimate of leg length in infants.

Statistical analysis

References for SH, LL and SH/H for age were constructed with the LMS method. The distribution of the data is summarised by three spline curves, the L, M, and S, that vary in time: the Box-Cox transformation power that converts data to normality and minimises the skewness of the dataset (L), the median (M), and the coefficient of variation (S) (7). The choice of the smoothing factors for the L, M, and S curves was made by creating local detrended QQ plots (8). The associations between SH SDS, LL SDS, SH/H SDS, SH/LL SDS and height SDS were calculated by (multiple) regression analyses and studied for 3 age groups: 0-<5 y (I), 5-<12.5 y (II) and 12.5-<21 y (III) of age. Two strategies were used to find the optimal cut-off values for height SDS and SH/H SDS. First, an ellipse was drawn around 95% of the data points in the scatterplot of SH/H SDS against H SDS, and points that were located outside the ellipse were classified as unusual. The second method was to select H SDS < -2 or >+2 first, and within that group, we classified all points as unusual that were located at least 2 SDS units away from the regression line of SH/H SDS given H SDS.

Results

Reference SD charts for SH and LL (Appendix 2), and SH/H for age (Appendix 2) were constructed for boys and girls aged 0-21 y (9). The corresponding L, M and S data are shown in table 1. In infants SH represents 68% of the length, decreasing to 57% at 3 y of age for both sexes. During puberty sitting height represents 52% of the height. Between 10 and 15 years a growth spurt in leg length is observed. The ratio SH/LL decreases from a mean of 2.10 in the first year to 1.05 in boys and 1.11 in girls at 20 year of age.

Table 2 shows the association between body proportions and height SDS. As expected, for both SH SDS and LL SDS a strong positive association with height SDS was found in all age groups. The correlations between SH/H (or SH/LL) SDS and height SDS were all negative and statistically significant ($p<0.001$).

Table 1. L, M, and S values for sitting height (SH) (cm), leg length (LL) (cm), and sitting height/height (SH/H) ratio for boys and girls of Dutch origin in the age-range 0-21 years.

				BOYS					
AGE		**SH**			**LL**			**SH/H**	
years	**L**	**M**	**S**	**L**	**M**	**S**	**L**	**M**	**S**
0.25	3.072	41.691	0.045	1.061	19.376	0.080	5.220	0.682	0.034
0.50	3.087	45.669	0.044	0.936	22.136	0.078	5.220	0.671	0.034
0.75	3.092	48.035	0.044	0.824	24.605	0.077	5.220	0.660	0.034
1.0	3.087	49.710	0.044	0.729	26.922	0.075	5.220	0.648	0.034
2.0	3.030	53.599	0.046	0.536	35.711	0.071	5.220	0.604	0.034
3.0	2.971	55.952	0.046	0.513	42.289	0.067	5.220	0.572	0.033
4.0	2.886	58.741	0.047	0.530	47.110	0.064	5.220	0.555	0.033
5.0	2.768	61.831	0.047	0.558	51.291	0.062	5.220	0.546	0.031
6.0	2.624	64.916	0.047	0.588	55.143	0.061	5.220	0.541	0.030
7.0	2.474	67.784	0.046	0.617	58.826	0.060	5.220	0.536	0.029
8.0	2.331	70.446	0.047	0.644	62.405	0.060	5.220	0.531	0.028
9.0	2.212	72.642	0.047	0.672	65.720	0.059	5.220	0.525	0.027
10.0	2.115	74.502	0.048	0.703	68.825	0.059	5.220	0.520	0.026
11.0	2.023	76.435	0.048	0.742	71.947	0.059	5.220	0.516	0.025
12.0	1.931	78.893	0.049	0.791	75.332	0.059	5.220	0.513	0.025
13.0	1.868	81.971	0.050	0.851	79.180	0.059	5.220	0.509	0.025
14.0	1.871	85.482	0.050	0.910	82.832	0.058	5.220	0.508	0.026
15.0	1.925	88.994	0.047	0.957	85.618	0.057	5.220	0.510	0.026
16.0	1.985	91.555	0.044	0.990	87.476	0.057	5.220	0.512	0.027
17.0	2.024	93.017	0.042	1.007	88.456	0.057	5.220	0.513	0.027
18.0	2.047	93.854	0.041	1.013	88.821	0.057	5.220	0.515	0.028
19.0	2.059	94.311	0.040	1.014	88.885	0.057	5.220	0.516	0.028
20.0	2.062	94.432	0.040	1.016	88.954	0.057	5.220	0.516	0.029
21.0	2.060	94.654	0.040	1.019	89.144	0.057	5.220	0.513	0.029

				GIRLS					
AGE		**SH**			**LL**			**SH/H**	
years	**L**	**M**	**S**	**L**	**M**	**S**	**L**	**M**	**S**
0.25	1.510	40.669	0.045	0.707	18.895	0.079	4.720	0.683	0.036
0.50	1.445	44.742	0.045	0.673	21.518	0.077	4.720	0.672	0.036
0.75	1.386	46.962	0.046	0.650	23.999	0.075	4.720	0.660	0.036
1.0	1.336	48.719	0.046	0.641	26.364	0.074	4.720	0.648	0.036
2.0	1.234	52.428	0.048	0.719	35.261	0.069	4.720	0.601	0.036
3.0	1.194	54.615	0.049	0.785	42.145	0.066	4.720	0.568	0.035
4.0	1.164	57.761	0.049	0.764	46.801	0.063	4.720	0.553	0.034
5.0	1.147	61.155	0.050	0.713	50.650	0.061	4.720	0.546	0.032
6.0	1.144	64.146	0.050	0.660	54.452	0.060	4.720	0.541	0.031
7.0	1.153	66.810	0.050	0.625	58.309	0.059	4.720	0.536	0.029
8.0	1.176	69.573	0.050	0.624	62.011	0.058	4.720	0.531	0.028
9.0	1.217	72.287	0.049	0.662	65.409	0.058	4.720	0.526	0.027
10.0	1.277	74.730	0.049	0.738	68.658	0.057	4.720	0.522	0.028
11.0	1.357	77.178	0.048	0.850	71.969	0.057	4.720	0.519	0.027
12.0	1.471	80.100	0.047	0.982	75.247	0.056	4.720	0.516	0.027
13.0	1.610	83.126	0.045	1.101	77.896	0.056	4.720	0.516	0.027
14.0	1.735	85.498	0.043	1.175	79.464	0.056	4.720	0.518	0.027
15.0	1.823	87.060	0.041	1.209	80.153	0.055	4.720	0.522	0.027
16.0	1.883	88.108	0.040	1.225	80.491	0.055	4.720	0.524	0.027
17.0	1.907	88.544	0.039	1.234	80.657	0.055	4.720	0.524	0.027
18.0	1.917	88.707	0.039	1.238	80.749	0.055	4.720	0.524	0.027
19.0	1.933	88.994	0.039	1.242	80.827	0.055	4.720	0.525	0.027
20.0	1.953	89.347	0.038	1.248	80.956	0.055	4.720	0.526	0.027
21.0	1.969	89.627	0.038	1.253	81.057	0.055	4.720	0.526	0.027

Table 2. Correlations between SH SDS, LL SDS, SH/H SDS, and SH/LL SDS and height SDS in three age groups.

	Age groups		
Correlation (r)	**0-<5 yr**	**5 - <12.5 yr**	**12.5-21 yr**
SH SDS - H SDS	0.61	0.63	0.80
LL SDS - H SDS	0.50	0.69	0.87
SH/H SDS - H SDS	-0.16	-0.23	-0.23
SH/LL SDS - H SDS	-0.15	-0.22	-0.24

This is illustrated in figure 1 presenting a scatter plot of SH/H SDS versus height SDS. The equiprobable ellipse around 95% of the points shows a tendency towards decreasing SH/H SDS with increasing height SDS. Vice versa, shorter children have higher SH/H ratios, thus relatively shorter legs. Data points located inside the ellipse may be considered as normal.

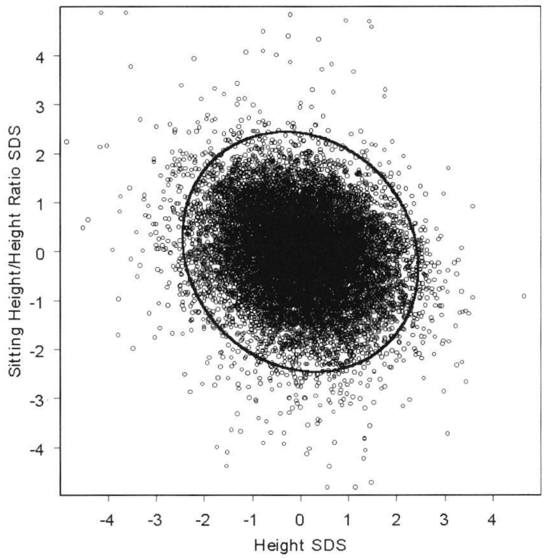

Figure 1. Scatter plot of SH/H SDS versus height SDS.

Figure 2 shows the ellipse, the regression line and two lines at 2 SDS units away of the regression line. This figure can be used as a nomogram to assess for a given height SDS the normal range of SH/H SDS. To explore if this nomogram is a useful tool to distinguish patients with Marfan syndrome from constitutionally tall children, or patients with hypochondroplasia from idiopathic short stature, one SH/H observation per patient from these groups of patients were plotted in the figure. Only in 3 out of 10 patients with Marfan syndrome SH/H was located below the conditional - 2 SD line, so this cut-off criterion has a sensitivity of only 30%. In 4 out of 10 patients SH/H SDS was below the unconditional -2 SD line. The ellipse criterion performed better: 6 out of 10 patients with Marfan were located outside the ellipse. When the conditional -2 SD line is taken as diagnostic criterion the likelihood ratio of a positive test (LR+) is 0.3/0.02=15, and the likelihood ratio of a negative test (LR-) 0.7/0.98=0.7. With regard to hypochondroplasia, a total of 8 out of 10 cases were located above the conditional +2 SDS line, corresponding to a sensitivity of 80%. This results in a LR+ of 40 and a LR- of 0.2. We observed that also here the ellipse performed better: all hypochondroplasia cases were located outside the ellipse.

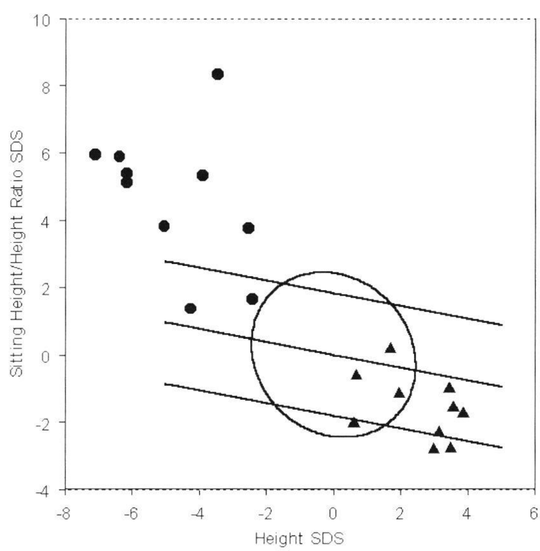

Figure 2. A nomogram to assess for a given height SDS the normal range of SH/H SDS, indicating the ellipse, the regression line, and two lines at 2 SDS units away of the regression line. ▲ hypochondroplasia. • Marfan Syndrome.

Figure 3A and 3B show sitting height/height data of the members of a family, with HCH due to a FGFR3 gene mutation on the maternal side. The sittingheight/height index of the index case and three of her female relatives is shown in figure 3A, and of her brother and uncle in figure 3B. The HCH mutation in the FGFR3 gene (in codon 540: substitution of asparagine by serine) caused a mild hypochondroplasia with a variable expression pattern. All affected family members had short stature (height <-2 SDS) and a mild increased sitting height/height index, indicating a disproportionate short stature with relatively short legs.

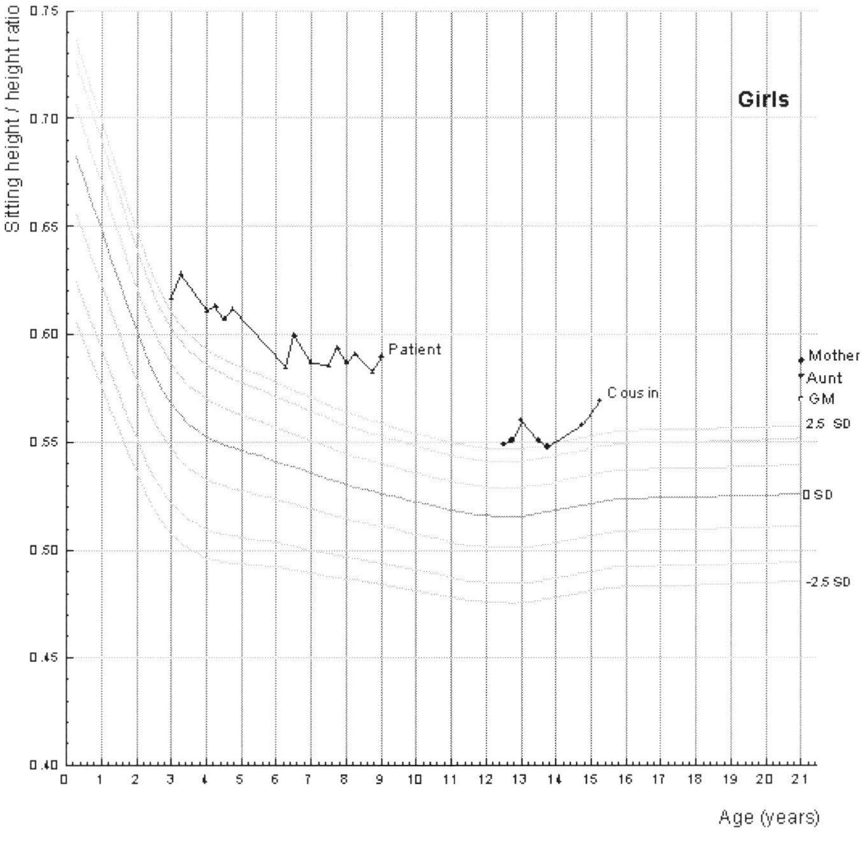

Figure 3A. SH/H data of the members of a family, with a HCH mutation in the FGFR3 gene on the maternal side, that caused a mild hypochondroplasia with a variable expression pattern. Figure A shows the SH/H index for the index case, her cousin, her mother, her aunt and grandmother.

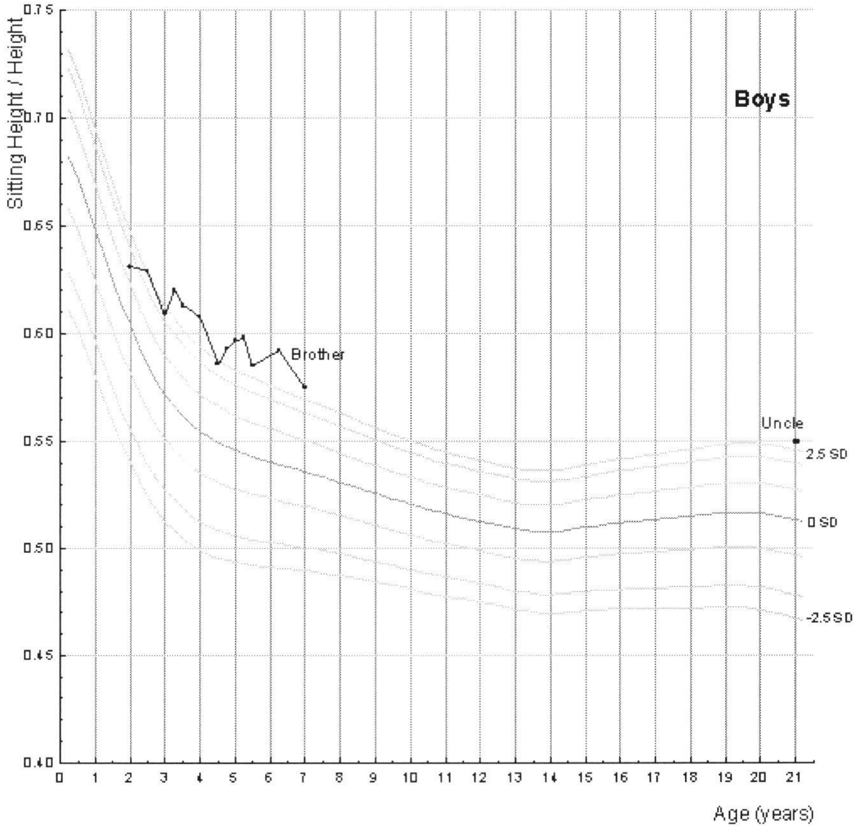

Figure 3B. Figure B shows the SH/H index for the brother and an uncle of the index case.

The negative correlation between SH/H SDS and H SDS signifies that for short or tall children the usual cut-off limits for body proportions (+ or - 2.0 SDS) would result in considerable percentages of children who would be considered as disproportionate. This is shown in table 3. If one would strive for a specificity of about 98%, the cut-off limit of SH/H SDS for short children would be +2.5 SDS, and for tall children -2.2.

Table 3. Percentages of short children (height SDS below -1.5 or -2.0) with a SH/H SDS >+2.0 or +2.5, and percentages of tall children (height SDS above +1.5 or +2.0) with a SH/H <-2.0 or -2.5.

	Short children			**Tall children**	
SH/H SDS	**H SDS <-2.0**	**H SDS <-1.5**	**SH/H SDS**	**H SDS >+1.5**	**H SDS >+2.0**
>+2.0	6.8%	3.6%	**<-2.0**	3.5%	5.2%
>+2.5	4.3%	2.5%	**<-2.5**	1.1%	1.7%

Discussion

This study provides new reference charts for Dutch children for SH, LL and SH/H in relation to age. The SH/H ratio changed from 0.68 infancy to 0.52 in adolescence, indicating that in the prepubertal years growth occurs more in the limbs than in the trunk. This is also shown by the decreasing SH/LL ratio from 2.10 to 1.08 at 10 years of age. The use of a ratio might be misleading when two ratios might be equal while the nominator and denominator might be different. This effect is even stronger when a change in the nominator automatically leads to a change in the denominater, for example by using SH/LL ratio. To minimize this risk, we chose for sitting height/height for age reference charts.

During the past two centuries in the Netherlands, as well as in many more industrialized countries, a positive secular growth change has been observed (6). Various studies have shown that the positive secular change is mainly due to increase in leg length rather than in trunk length (1,4,10-13). Tanner described that between the nineteenfifties and eighties Japanese height increased solely due to change in leg length. Sitting height showed no increase, so the trunk/leg proportions changed much more towards the proportions of North Europeans, though their final height was still 1 SD lower (14).

Secular trend may explain part of the difference we observed between our study and the Oosterwolde study, a previous (regional) Dutch growth study including sitting height measurements and performed in 1980 and 1990 (15). We found that our reference lines for SH for age and SH/H ratio for age were usually lower than the Oosterwolde study. Despite the fact that the Oosterwolde sample consisted of relatively tall children from the Northern part of the Netherlands, the 1997 Dutch population was even taller. The Oosterwolde study showed that in 10 years (1980-90) the increase in height was more pronounced than the increase in sitting height, so the major secular change must have been in the legs (1). In the three previous national Dutch growth studies no data on body proportions were collected, so that we cannot comment on the secular trend with respect to body proportions. Our present data on sitting height, leg length and height reference values in the Netherlands are higher than in Denmark, UK and Sweden (16), illustrating our earlier observations (6) that the Dutch population is probably still the tallest in the world (mean height for men 184.0 cm, for women 170.6 cm).

We have shown that in short children a cut-off of 2.5 SDS is better than a cut-off of 2 SDS and that in tall children a cut-off limit of -2.2 SDS can be used. However, we think that instead of using fixed cut-off limits, one can better plot individual observations on the diagram of SH/H SDS versus H SDS.

The sensitivity of the conditional ±2 SD cut-off limits for detecting hypochondroplasia and Marfan syndrome on the reference chart was studied by comparing body proportions of these two patient groups to the reference population. Based on the values of the positive and negative likelihood ratios of the conditional cut-off limit, the diagnostic value of assessing body proportions for hypochondroplasia is good. For Marfan syndrome, the LR+ is high (15), but the LR- not much lower than one, suggesting that normal body proportions do not exclude Marfan syndrome. For both patient groups the equiprobable ellipse is a better criterion to detect growth disorders than the ±2 SD lines method. Further investigations on larger groups of patients are necessary to further validate the clinical usefulness of abnormal body proportions for the detection of these and other growth disorders.

Eveleth and Tanner (17) described that differences in body proportions are genetically controlled and different for European, African and Oriental populations (Caucasians have tall stature with long legs, in contrast to Orientals). With better environmental circumstances relatively longer legs appear in all ethnic groups. In fact, monitoring leg length might even be a better tool for reflection of environmental improvements than height. Abused children, who have relatively short legs, showed after social interventions a significant recovery of leg length (18). In our study on body stature, mean height was related to geographical region, family size and educational level of the parents and the child (6). In the present study geographical region was only a significant predictor in the youngest group (data not shown). No significant differences were found for educational level or gender.

One of the problems in assessing body proportions is that errors in SH measurement are easily made, which can lead to considerable inter-observer variation. We did not study the inter-observer variance for sitting height measurements, but in the Fels Longitudinal Study the mean absolute interobserver difference was 0.5 cm (SD 0.3 cm) for crown-rump length and 0.3 cm (SD 0.2 cm) for sitting height (19).

In conclusion, new reference charts for sitting height, leg length and body proportion are presented. There was a statistically significant negative correlation between SH/LL and SH/H and height. For practical purposes, in an exceptionally short child a SH/H ratio below +2.5 SDS and in a tall child a SH/H ratio above –2.2 should still be considered normal. The nomogram for SH/H SDS versus H SDS is a useful tool in the work-up of children with growth disorders and provides an objective basis for recognizing disproportionate growth.

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Chapter 4

Pubertal development in the Netherlands 1965 – 1997

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Abstract

Objectives We investigated pubertal development of 4,019 boys and 3,562 girls > 8 years of age participating in a cross-sectional survey in the Netherlands and compared the results with those of two previous surveys, using similar methodology.
Method Reference curves for all pubertal stages were constructed.
Results The 50th percentile of Tanner breast stage 2 was 10.7 years, and 50% of the boys had reached a testicular volume of 4 ml at 11.5 years of age. Median age at menarche was 13.15 years. The median age at which the various stages of pubertal development were observed has stabilized since 1980. The increase of the age at stage G2 between 1965 and 1997 is probably owing to different interpretations of its definition.
The current age limits for the definition of precocious puberty (8 years for girls, 9 years for boys), are close to the 3rd percentile of these references. A high agreement was found between the pubic hair stages and stages of pubertal (genital and breast) development. But slightly more in boys than in girls. Menarcheal age was dependent on height, weight, and body mass index. At a given age tall or heavy girls have a higher probability of having menarche compared with short or thin girls. A body weight exceeding 60 kg (+1 SDS), or a BMI of > 20 (+1 SDS), has no or little effect on the chance of having menarche, whereas for height such a ceiling effect was not observed.
Conclusion In the Netherlands the age at onset of puberty or menarche has stabilized since 1980. Height, weight, and body mass index have a strong influence on the chance of menarche.

Introduction

The development and first appearance of secondary sexual characteristics can be regarded as a reflection of the overall physiological development in adolescence (1). The continuous process of pubertal development is usually subdivided into discrete numerical stages, as proposed by Marshall and Tanner (2,3).

The assessment of pubertal stages in the individual child or adolescent in the clinic is only useful if recent and reliable reference data from the same population are available for comparison. As in many European countries a positive secular trend with regard to height, accompanied by a decrease of the age at onset of puberty (1,4,5), has been observed, nation-wide reference data should be collected at 10- to 20-y intervals. If te age at onset of puberty would indeed decrease, the definition of precocious and delayed puberty should be adjusted. In fact, in the United States it was recently proposed to revise the guidelines for the evaluation of girls with precocious puberty (6,7).

Besides clinical reasons, there are also scientific reasons to study pubertal development in a large population-based sample of healthy children and adolescents. First, it is unclear if the secular trend with regard to body stature is invariably associated with a trend toward earlier pubertal development. Second, there are few data on the association between the markers of the maturation process of the hypothalamo-pituitary-gonadal axis (breast development in girls and genital stage in boys) and the occurrence of pubic hair. One would suspect that the agreement between gonadal (G or B stage) and pubic hair development (PH stage) should be higher in boys than in girls, as pubic hair is caused by androgen production. Third, there are observations suggesting that pubertal development is influenced by anthropometric variables, particularly body weight (8,9), but the exact nature of the correlation is unknown.

In the Netherlands four consecutive growth studies have been performed since 1955 (1,10-12). These studies provide the opportunity to thoroughly study the secular changes in height, weight and pubertal development. In two earlier papers on the study performed in 1997, we concentrated on the secular trend of body stature, weight and body mass index (BMI) and only briefly discussed pubertal development (12,13).

In the present paper we report on the reference data in more detail, as well as a comparison with the previous growth studies. Furthermore, we investigated the degree of concurrence of breast or genital stages with pubic hair stages, and the relationship between the age at menarche and height, weight, and BMI.

Methods

In a cross-sectional design the presence of secondary sexual characteristics was studied. All participants of the 1997 nation-wide growth study aged ≥9 years completed a questionnaire on demographic variables (3,909 boys and 3,454 girls). This sample can be regarded as representative for the general population. In a subgroup ('puberty sample') we determined the stage of sexual maturation and age at menarche. The age distribution in the puberty sample showed an overrepresentation of children <15 years of age (approximately 250 in each age group) compared with children >15 years (100 – 150 per each group; table 1).

Table 1. Puberty sample: percentage of participating boys and girls per age group as percentage of the total age group included in the 1997 Dutch National Survey.

Age (yrs)	PH boys %	G boys %	TV boys %	PH girls %	B girls %	Menarche %
8-9	49.1	49.1	42.7	60.2	61.1	59.3
9-12	73.2	72.9	66.5	78.1	80.5	85.6
12-15	54.4	54.3	51.3	57.4	58.5	76.9
15-18	49.9	49.9	47.6	51.1	52.1	74.8
18-21	42.5	42.4	40.4	33.6	33.9	83.8

*4,019 boys and 3,562 girls
Abbreviations: PH, pubic hair; G, genital stage; TV, testicular volume; B, breast stage.

Data were available from an additional group of 110 boys and 108 girls between 8 and 9 years of age who had also completed the questionnaire. Pubertal data were available from approximately 50% of these children (table 1). These observations were randomly distributed across the country.

In the analyses in this article age was used as covariate, so this skewed age distribution will not affect the results. The composition of the puberty sample was comparable with the sample of a national survey with regard to region and level of education.

The measurements of height and weight were performed by trained staff. The pubertal stages were determined by visual inspection, using Tanner's criteria (14) as described in table 2.

In boys testicular volume was assessed using an orchidometer. To validate the accuracy of the measurement of testicular volume, the testicular volumes in 79 boys were measured by 2 observers. The Spearman correlation coefficient between the measurements of 2 observers was 0.82; the 95 % confidence interval for the difference between observers appeared to be 0.4–2.0 ml (1.2 ± 0.8 ml). In midpuberty the interobserver differences were highest. Zachman *et al* (15) reported a correlation coefficient of 0.83 and a mean difference in testicular volume between 2 observers of 2.9 ml. The age at menarche was determined by the status quo method, asking a girl whether she had had her first period at the moment of the survey.

Demographic variables were assessed by a questionnaire. The highest level of completed education of the parents was used as a measure for socio-economic status.

The country was divided in five geographical regions, one of them containing the four largest cities (13).

Table 2. Definitions of Tanner stages

Sex	Tanner Stage	Description
F	B1	Preadolescent; elevation of papilla only
	B2	Breast bud stage; elevation of breast and papilla as a small mound, enlargement of areolar diameter
	B3	Further enlargement of breast and areola, with no separation of their contours
	B4	Projection of areola and papilla to form a secondary mound above the level of the breast
	B5	Mature stage; projection of papilla only, owing to recession of the areola to the general contour of the breast
F	PH1	Preadolescent; no pubic hair
	PH2	Sparse growth of long, slightly pigmented downy hair, straight or only slightly curled, appearing chiefly along the labia
	PH3	Considerably darker, coarser, and more curled; spreads sparsely over the conjunction of the pubes
	PH4	Hair is adult in type, but the area covered by it is still considerably smaller than in most adults. There is no spread to the medial surface of the thighs
	PH5	Adult in quantity and type, distributed as an inverse triangle of the classic feminine pattern. Spread to the medial surface of the thighs, but not up the linea alba or elsewhere above the base of the inverse triangle
M	G1	Preadolescent; testes, scrotum, and penis are of about the same size and proportion as in early childhood
	G2	The scrotum and testes have enlarged and there is a change in the texture of the scrotal skin. There is also some reddening of the scrotal skin
	G3	Growth of the penis has occurred, at first mainly in length but with some increase in breadth. There has been further growth of testes and scrotum
	G4	Penis further enlarged in length and breadth with development of glans. Testes and scrotum further enlarged. Further darkening of the scrotal skin
	G5	Genitalia adult in size and shape. No further enlargement takes place after stage 5 is reached
M	PH1	Preadolescent; no pubic hair
	PH2	Sparse growth of long, slightly pigmented downy hair, straight or only slightly curled, appearing chiefly at the base of the penis
	PH3	Considerably darker, coarser, and more curled; spreads sparsely over the junction of the pubes
	PH4	Hair is adult in type, but the area covered by it is still considerably smaller than in most adults. There is no spread to the medial surface of the thighs
	PH5	Adult in quantity and type, distributed as an inverse triangle of the classical feminine pattern. Spread to the medial surface of the thighs, but no up the linea alba or elsewhere above the base of the inverse triangle

Descriptions are taken from Marshall and Tanner (2,3). Abbreviations: B, breast stage; PH, pubic hair stage; G, genital stage; F, females; M, males.

Statistical methods

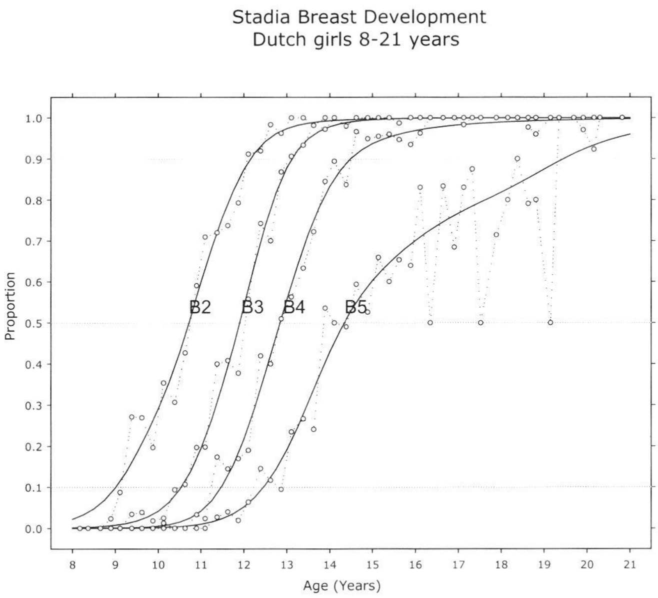
For menarche and stages of secondary sexual characteristics, the reference curves were estimated by a generalised additive logistic model for each stage transition separately (16). This model describes the probability of each stage as a smooth function of age. The amount of smoothing was determined by cross-validation. LMS reference curves were derived for testicular volumes, in which the measured volumes were considered as a continuous measure (17). To compare B or G stages and pubic hair stages in girls and boys we calculated kappa (κ) as measure of agreement (18).

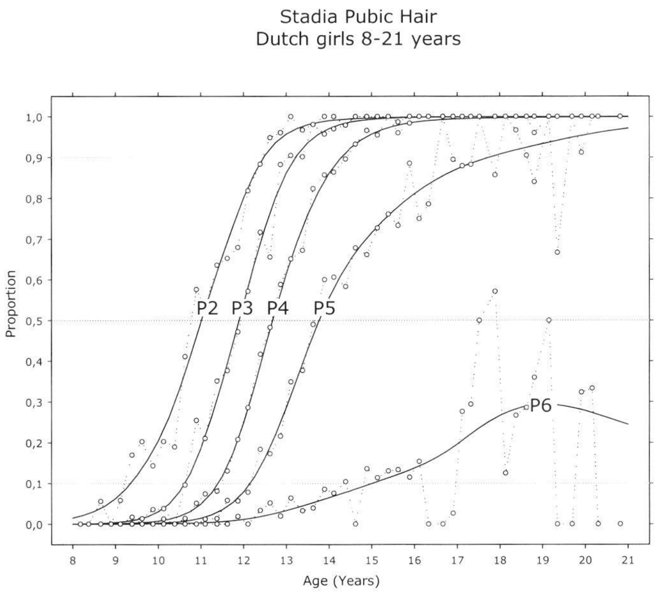
Results

Reference curves for pubertal stages and testicular volume.

In figure 1 A-G, we present the reference curves for sexual development. The dotted lines represent the crude data. The P_{50} ages can be read from the figures. The 10th and 90th percentile ages, which were published earlier as numerical data (12), can also be read from these graphics, being the ages at which the curves cross the 10th and 90th percentiles, respectively.

Figure 1 also shows the intervals between the consecutive pubertal stages, with a general pattern of a shorter interval between the third and fourth stage compared to the interval between stages 2 and 3. In figure 1G, reference curves are presented for various testicular volumes. The P_3 for B2 and G2 were 8.2 and 9.8 years respectively, the P_{97} values were 12.7 and 13.4 years respectively


Stadia Breast Development
Dutch girls 8-21 years
Proportion
Age (Years)
B2
B3
B4
B5
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8
9
10
11
12
13
14
15
16
17
18
19
20
21


Stadia Pubic Hair
Dutch girls 8-21 years
Proportion
Age (Years)
P2
P3
P4
P5
P6
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
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0,0
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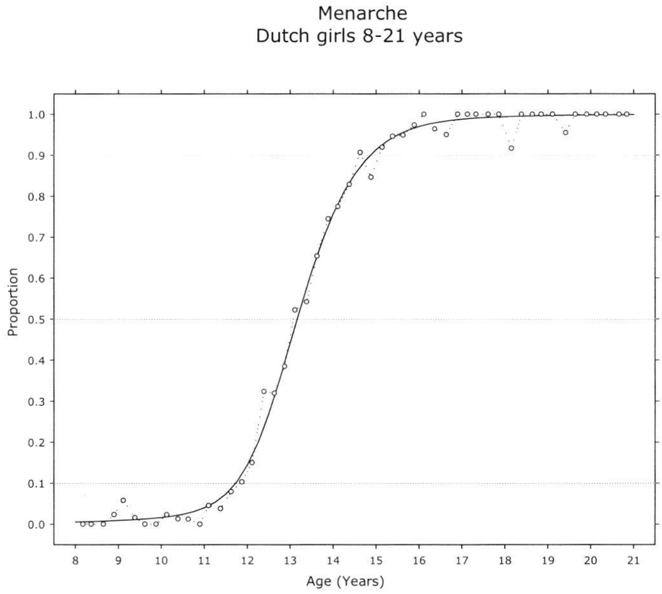
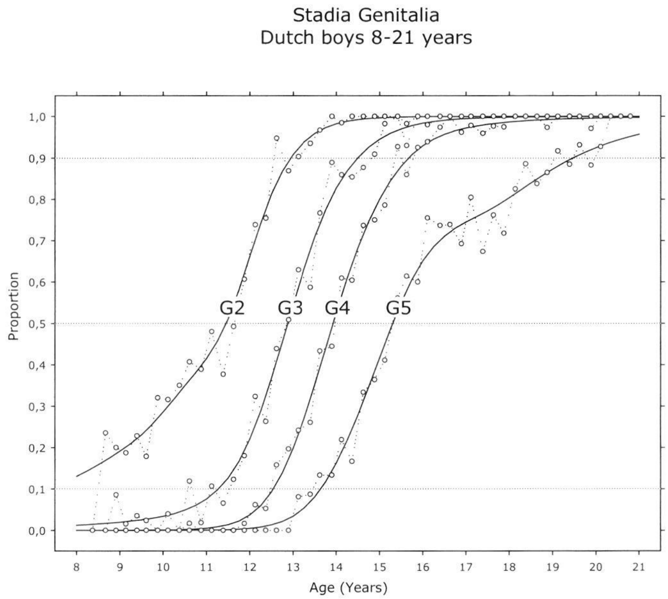
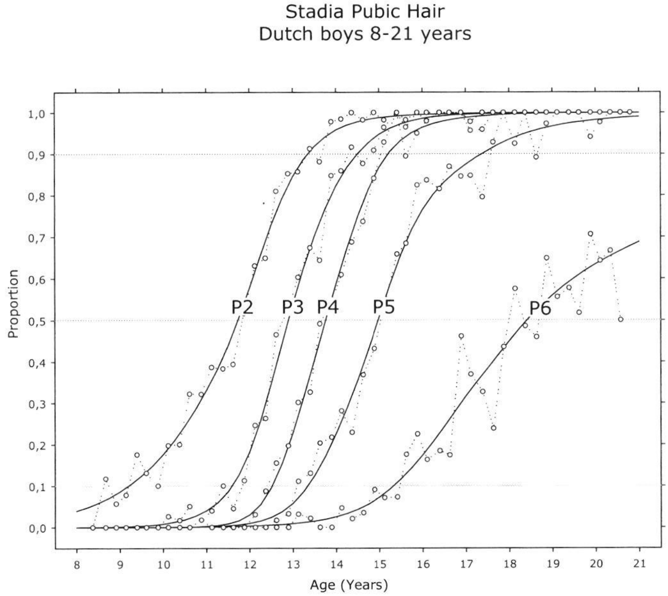
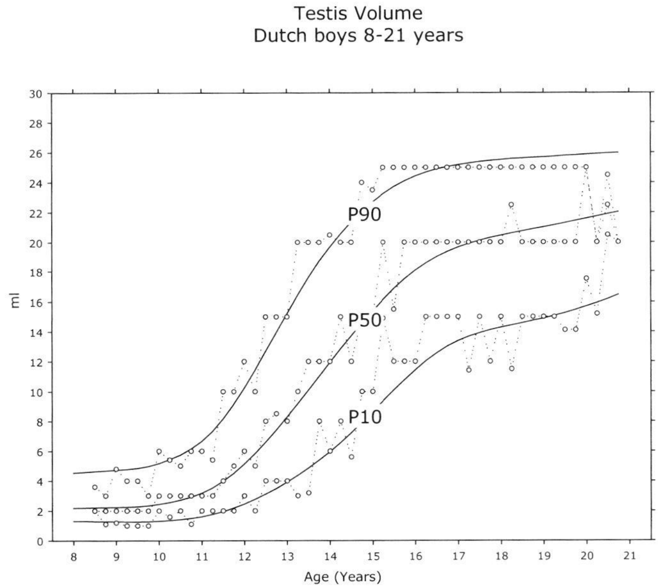

Menarche
Dutch girls 8-21 years
Proportion
Age (Years)


Stadia Genitalia
Dutch boys 8-21 years
G2
G3
G4
G5
Proportion
Age (Years)


Stadia Pubic Hair
Dutch boys 8-21 years
Proportion
P2
P3
P4
P5
P6
Age (Years)


Testis Volume
Dutch boys 8-21 years
ml
P90
P50
P10
Age (Years)

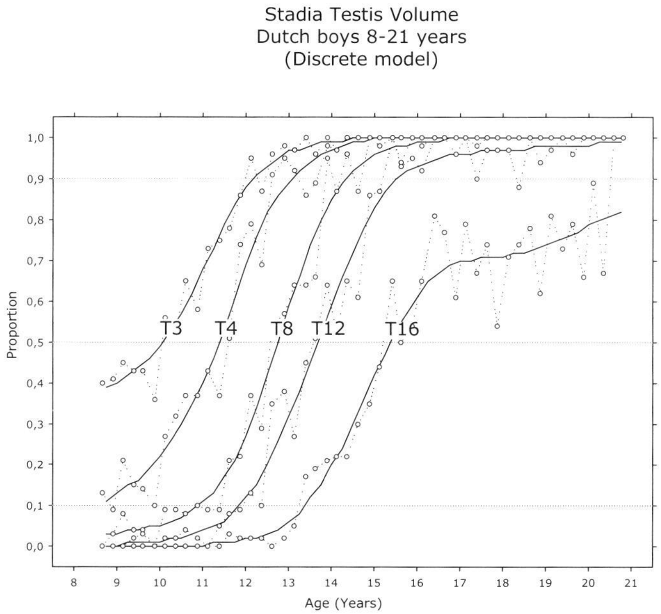
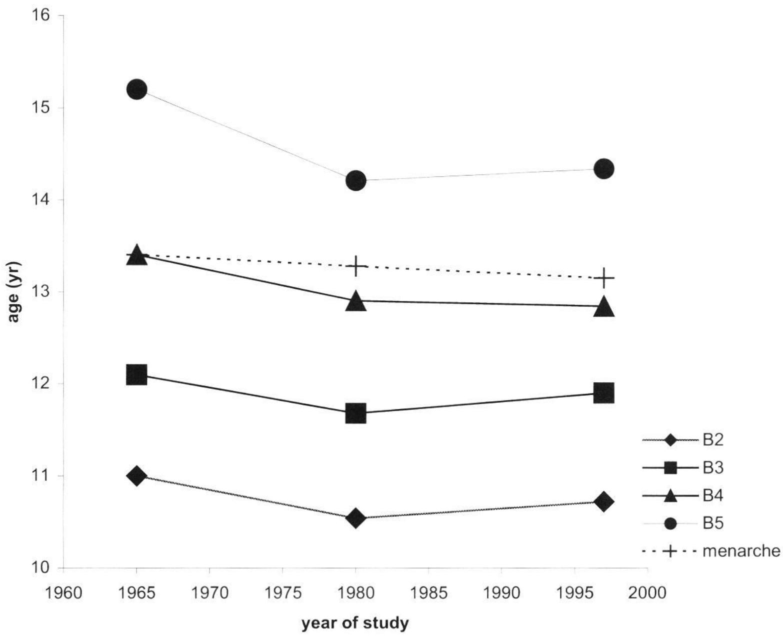


Figure 1 A-G. Reference curves for secondary sexual characteristics in the Netherlands, 1997. A, breast stage in girls; B, pubic hair stage in girls; C, menarche; D, genital stage in boys; E, pubic hair stage in boys; F, mean testicular volume; G, testicular volumes in early and midpuberty (3,4,8,12, and 16 ml).

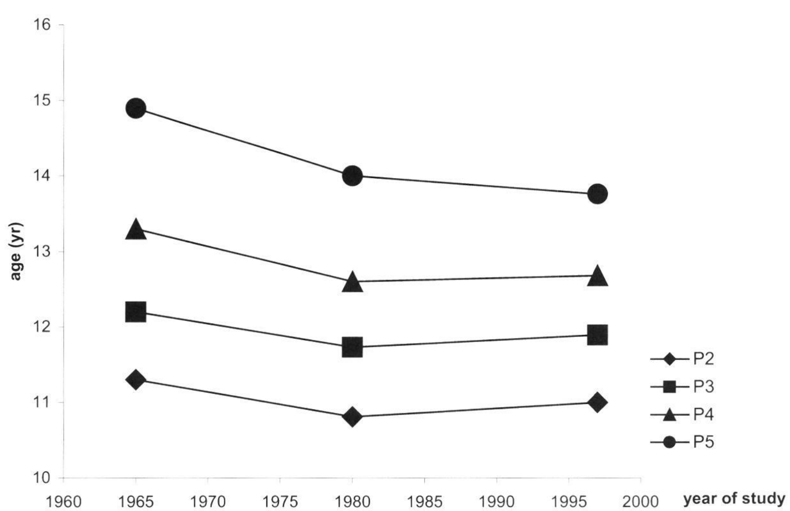
Comparison with the 1965 and 1980 growth studies.

In figure 2, we show comparisons between the timing of pubertal stages in the present study and the previous growth studies performed in 1965 and 1980. The P_{50} values are shown for both boys and girls. For all stages a decreasing trend is seen between 1965 and 1980 with stabilization afterward. In contrast, G2 in boys increased from 11 y in 1965 to 11.5 y in 1997, whereas the P_{50} of a testicular volume of 4 ml decreased from 12 y in 1965 to 11.5 y in 1997. In all studies the SD of the P_{50} ages is approximately 1 year.

2 a


16
15
14
13
12
11
10
age (yr)
1960
1965
1970
1975
1980
1985
1990
1995
2000
year of study
B2
B3
B4
B5
menarche

2 b


16
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age (yr)
1960
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P2
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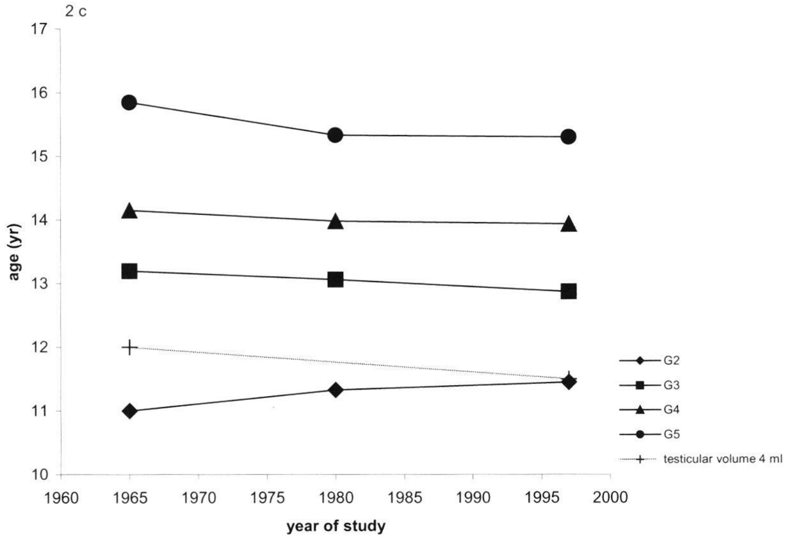
P4
P5



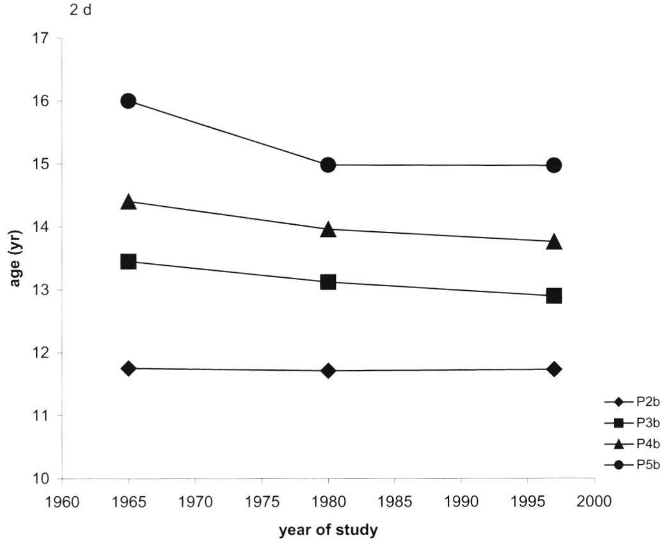


Figure 2 A-D. Sexual maturation in the Netherlands 1965 – 1997 (1,12, and this study); the P_{50} values of the different pubertal stages are given. A, breast stage and menarche; B, pubic hair stage in girls; C, genital stage in boys and testicular volume 4 ml; D, pubic hair stage in boys.

Relationship between pubertal stages.

In table 3 the relationships between the PH stage and B or G stages are shown in absolute numbers. In girls in B1, 60 of 531 (11.3%) showed pubic hair development, whereas 23.3% of girls in PH1 showed breast development. In boys, G1 was accompanied by the presence of pubic hair in 10.2%; boys in PH1 had genital development in 24.9%.

The agreement between PH and B or G stage was expressed as kappa (κ) and Spearman correlation. The κ values were 0.59 and 0.63 for girls and boys, respectively, indicating moderate to substantial agreement. The difference between the 2 κ values was significant ($p<0.05$). Spearman rank-order correlation was 0.91 both in boys and girls ($p<0.001$).

Thus, in line with our hypothesis, in boys the gonadal and pubic hair development shows a closer mutual agreement than in girls, although the difference in kappa is only small.

Table 3A. Distribution of B and PH stages in girls.

***n*=2213**	**B1**	**B2**	**B3**	**B4**	**B5**	**Total**
PH1	471	124	19	~	~	614
PH2	55	138	50	3	1	247
PH3	5	50	118	36	6	215
PH4	~	4	58	186	71	319
PH5	~	~	17	156	495	668
PH6	~	~	5	23	122	150
Total	531	316	267	404	695	2213

kappa= 0.59 ($p<0.001$).

Table 3B. Distribution of G and PH stages in boys.

***n*=2360**	**G1**	**G2**	**G3**	**G4**	**G5**	**Total**
PH1	529	151	21	2	1*	704
PH2	59	222	53	4	~	338
PH3	1	47	124	20	1	193
PH4	~	2	56	178	32	268
PH5	~	1	10	130	387	528
PH6	~	~	1	15	313	329
Total	589	423	265	349	734	2360

kappa= 0.63 ($p<0.001$); * this boy was 17.1 years old, testicular volume 20 ml.

Menarcheal age in relation to auxological variables

In figure 3 the probability of having menarche is depicted as function of age (x-axis) and weight, weight SDS, height, height SDS, BMI and BMI SDS (plotted on the y-axis). All figures show the expected increase in probability of menarche with increasing age and the additional effect of weight, height and BMI (expressed as nominal values or as SDS).

They demonstrate that at a given age the heavier and taller girls have a higher probability of having menarche. However, the shape of the probability curves is different for the indices of weight (i.e. weight and BMI) in comparison to height. When weight or BMI exceeds a certain point, no or little further increase in probability is observed, as the curves have an almost vertical course from there. For weight this point is close to 62 kg (1 SDS), and for BMI it is approximately 20 kg/m^2 or 1 SDS. In the curve for weight expressed in kilograms, the vertical course is more obvious than in the curve for weight SDS. In contrast, the figures on height show a continuing effect of height at a certain age. Some examples of the different ages at which there is 50% probability for having menarche with various SDS for weight, height or BMI are shown in table 4.

Table 4. Influence of different SDS for weight, height, and BMI on the P_{50} age of chance of having menarche.

	SDS	**Age P_{50} (yr)***
Weight	+2	12.1
	+1	12.7
	0	13.2
	-1	13.8
	-2	14.5
Height	+2	12.2
	+1	12.8
	0	13.3
	-1	13.7
	-2	14.0
BMI	+2	12.7
	+1	12.7
	0	13.1
	-1	13.8
	-2	14.7

* estimated from the curves in fig 3 B, D, and F.

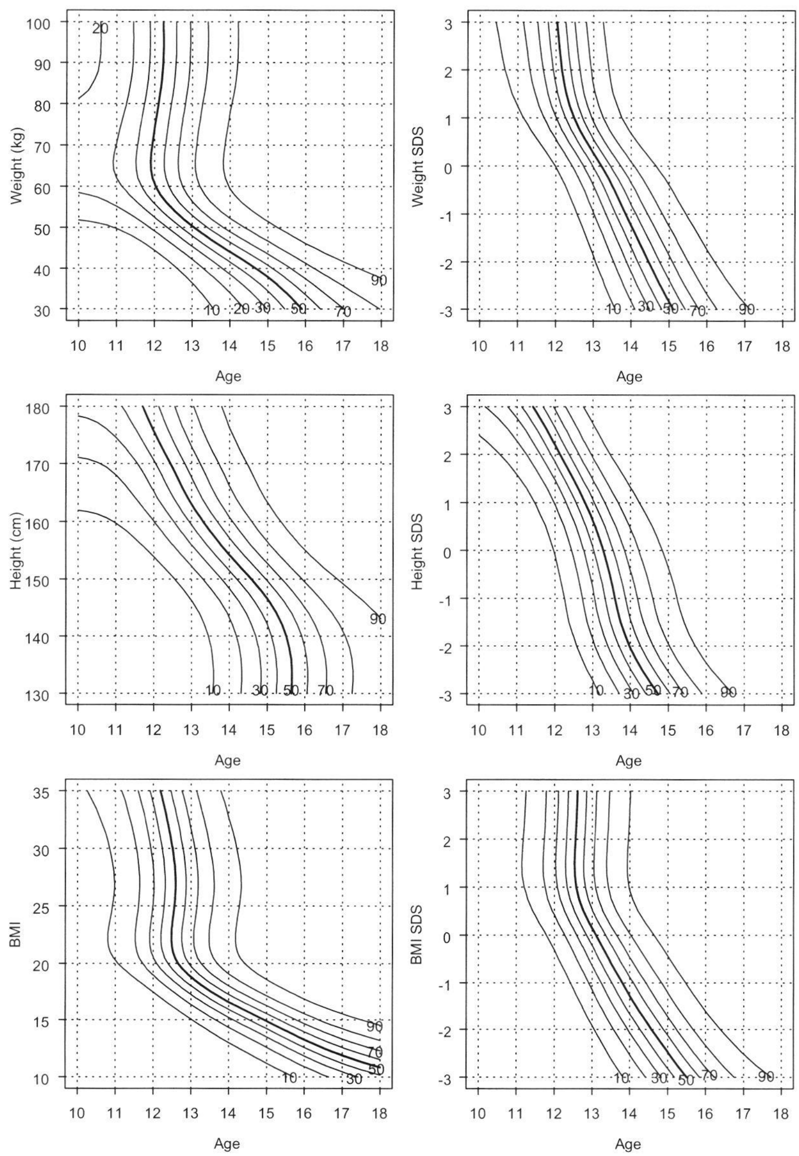


Figure 3A-F. Probability of having menarche as a function of age and weight (A), weight SDS (B), height (C), height SDS (D), BMI (E), and BMI SDS (F). The probability is expressed as a percentage. A vertical course of the lines means that at a certain age the variable on the *y*-axis does not further contribute to increase the probability of having menarche. A transverse course implies additional effect of the variable of the *y*-axis on the probability of having menarche.

Discussion

This study provides up-to-date references for pubertal stages in the Dutch population, which can be used for clinical purposes. In the interpretation of the reference curves for the consecutive pubertal stages, one should be aware, however, that our data are derived from a cross-sectional study. The reliability of the data is high, due to the relatively large numbers of subjects. On the other hand, no information is available about the tempo at which a child passes through the consecutive stages. Such information can only be obtained by a longitudinal study, like the longitudinal assessment of puberty in boys and girls performed by Marshall and Tanner (2,3). In general, reference centiles based on cross-sectional data have a larger variance than those based on longitudinal data. For pubertal development curves, this implies that the progression of stages for individuals is generally faster than the intervals between P_{50}-stages obtained from cross-sectional references.

The second finding is that the positive secular change towards an earlier development of puberty between 1965 and 1980 has almost stabilized thereafter. During the whole period between 1965 and 1997 the P_{50} age of onset of puberty (stage B2) in girls decreased from 11.0 years in 1965 to 10.7 years in this study. The median age at menarche decreased by 0.25 y in the same period, and by 0.5 y from 1955. In the last 17 years only a small decrease of about 1.5 months from 13.28 to 13.15 years was observed. A similar pattern of an apparent stabilization of a previously decreasing trend was observed in Oslo schoolgirls, in whom menarcheal age has reached a stable level for several decades (19). However, in Norway also the secular trend in body stature appears to have stopped (19). Maybe the stabilization reflects a situation in which the environmental conditions have allowed the child to reach the optimal genetic potential given the actual environmental conditions (4).

The only exception to this trend of a slow positive secular trend between 1965 and 1980 followed by near stabilization is the apparent increase of the median age at which boys reach G2 from 11.0 years in 1965 to around 11.5 years in 1997. This finding contrasts with a decrease of the median age at attaining a testicular volume of 4 ml from 12.0 years in 1965 to 11.5 years in 1997. The most likely explanation of this discrepancy is that the interpretation of the definition of stage G2 must have been different in 1965 in comparison to 1980 (1,20) and 1997.

In fact, the original definition of G2 as proposed by Marshall and Tanner (3) leaves much room for confusion, as it states that 'The scrotum and testes have enlarged and there is a change in the texture of the scrotal skin. There is also some reddening of the scrotal skin ....' (see also table 2). This description is not pertinent to the question of which of the three criteria mentioned is most relevant, and to whether all criteria have to be met or at least one or two of them. In addition, it does not strictly describe the minimum volume that the testis should have before the genital stage may be labeled as G2. For example, there are good arguments that a testicular volume of 3 ml can already be considered as a sign of puberty (15,21). In the present study the observers were taught to describe the genital stage as G2 if both enlargement of testicular volume and scrotum was observed and reddening of the scrotal skin was present. It appears likely that in 1965 the observers might have labeled the genital stage as G2 if at least one of the three criteria was present.

Based on these findings, but also on our experience in clinical trials (22), we believe that it is opportune to come to a redefinition of stage G2, to prevent more confusion in the future. We would prefer that the testicular volume, the criterion that is most easily measured, should be used as the only criterion. Furthermore, a volume of 3 ml appears a better indication of the onset of puberty than 4 ml (21,23).

Relatively few data are available on the accordance between PH and G or M stages during puberty. Based on the theoretical view that, for girls, breast development is the initial event in pubertal development and testicular development for boys, these parameters should be used as markers in clinical practice. In girls, PH stage is primarily a reflection of adrenal maturation although the role of ovarian androgens is acknowledged in pubertal girls (24). In boys, PH stage is the reflection of a combined adrenal and testicular maturation, so that a higher agreement would be expected in boys than in girls. In fact, we found a higher agreement between PH and G or B stage (expressed as kappa) in boys than in girls, but both were significant. This suggests that pubertal development and pubic hair development frequently synchronize. With regard to the timing of both phenomena, we found that in general breast development starts somewhat earlier than pubic hair, in line with the findings of Marshall (2). However, pubic hair was seen before breast development in approximately one third of all girls in the English study (2), and in approximately 10 % in our study. In stages B3 and G3 the distribution of PH stages is equally divided and in the higher B or G stages the PH scores tend to shift to the right, especially in boys, with higher PH than G or M stage.

The definition of precocious puberty and delayed puberty should be based on the normal occurrence of secondary sexual characteristics in the population, but there is no consensus whether -2 SDS or -2.5 SDS should be used as a cut-off. We chose to use the usual cut-off measure of -2 SD, which is close to the P_3, and can be read from the reference curves in figure 1.

The P_3 age for B2 (8.2 years) is close to the age of 8.0 years, which is generally and internationally used as age limit for the definition of precocious puberty, and we would therefore propose to continue using this figure. For boys the P_3 of G2 stage is 9.8 years, whereas no reliable P_3 data for testicular volume of 4 ml can be presented.

Thus, the current cut-off ages for precocious puberty, i.e. 8 years for girls and 9 years for boys, can be maintained in our country.

For delayed puberty, the P_{97} for B2 and G2 presented in the results section, as well as the P_{97} age for testicular volume of 4 ml (13.8 years), point to a cut-off age for delayed puberty of 13 years in girls and 14 years in boys.

As mentioned before, in the United States a decrease in the age at onset of puberty in girls was observed (6). However, in that study the sample was not representative for the general population, as the girls were examined when they visited a general practitioner. The girls were heavier and taller than in the national American growth survey, and in 15% of the girls rated B2 by visual inspection no breast tissue was found at palpation (7).

We have shown that in addition to age, weight, height and BMI influence the chance of having menarche in the age range 11-15 years as well. Interestingly, the probability lines for weight and BMI show an almost vertical pattern in the range where the SDS exceeds approximately 1. Beyond such degree of (over)weight, weight or BMI hardly affects the probability of having menarche anymore. The cut-off level for BMI data are consistent with the results published in our earlier report, showing that premenarcheal girls in all age ranges had mean BMI < 20 kg/m^2 (13). Our data are in contrast to those of Marshall (25), who stated that the occurrence of menarche was not related to the attainment of a particular height, weight or body composition, but mostly occurred after the peak of the adolescent growth spurt. However, the limited number of subjects in that study may have precluded the appearance of statistical significance in this respect. An interesting phenomenon is that height, in contrast to weight and BMI, exerts its influence on the probability of menarche over the full range.

It is generally assumed that the increase in socio-economic conditions and general health is the main contributing factor for the trend towards earlier maturation (4,26,27). In most industrialized countries the increase in public health and socio-economic conditions was accompanied by an increase in adult height and a decreasing age at attainment of pubertal events (28). The mechanisms through which these changes occur are unknown. On the physiological substrate for earlier pubertal development several hypotheses were discussed, for example, the so-called critical weight hypothesis (8,29). Recent studies on leptin have suggested that this protein could act as a link between fat tissue and the central activation of the hypothalamus (30-32). Another line of research concerns the possible influences of estrogen-like substances in the environment on the timing of puberty, for example, phyto-estrogens present in soy-based feeding (33). However, no human data are available that show an influence of infant feeding, containing phytoestrogens, on sexual maturation (34). The stabilization of the age at onset of puberty at in a period where an increasing exposure to estrogenlike substances can be assumed, argues against a causal link.

We conclude that the secular change toward earlier puberty has been stabilized in the last two decades in the Netherlands. No change in the definition of precocious puberty is warranted. The occurrence of menarche is not only dependent on age, but also on height, weight, and BMI. Beyond a weight or BMI of +1.0 SDS this dependency is less apparent. The agreement between the expression of gonadal maturation and pubic hair is slightly higher in boys than in girls.

Acknowledgements

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Chapter 5

Body mass index measurements in 1996-7 compared with 1980

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Abstract

Objective To compare the distribution of body mass index (BMI), in a national representative study in the Netherlands in 1996-7, with that from a study in 1980.

Methods Cross-sectional data on height, weight, and demographics of 14,500 boys and girls of Dutch origin, aged 0-21 years, were collected from 1996 to 1997. BMI references were derived using the LMS method. The 90th, 50th and 10th BMI centiles of the 1980 study were used as baseline. Association of demographic variables with BMI SDS was assessed by ANOVA.

Results BMI age-reference charts were constructed. From 3 years of age onwards 14-22% of the children exceeded the P_{90} of 1980, 52-60% the P_{50} and 92-95% the P_{10}. BMI was related to region, educational level of parents (negatively), and family size (negatively). The –0.9, +1.1, and +2.3 SD lines in 1996-1997 corresponded to the adult cut-off points of 20, 25, and 30 kg/m^2 recommended by the World Health Organization/European childhood obesity group.

Conclusion BMI–age references have increased in the past 17 years. Therefore, strategies to prevent obesity in childhood should be a priority in child public health.

Introduction

Body mass index (BMI, kg/m^2) as a measure for underweight and overweight, is widely accepted. For adults, a pragmatic classification system exists, based on associations between body mass index and all cause mortality (1). Recently, BMI cut-off values for adults were redefined and divided into six classes: <18.5 kg/m^2, underweight; 18.5-24.9 kg/m^2, ideal weight; 25.0-29.9 kg/m^2, pre-obese; 30.0-34.9 kg/m^2, obese class I; 35.0-39.9 kg/m^2, obese class II; and $\geq$ 40 kg/m^2, obese class III (2,3). Compared with two other weight for stature indices (kg/m and kg/m^3) BMI better fits the conditions of low correlation with height and high correlation with weight and skinfold thickness (4).

In children, BMI has been recommended as measure for overweight (5) and child BMI-age reference charts have been published in several countries (6-12). Because BMI is dependent on age and pubertal status, individual BMI values should be expressed as BMI standard deviation scores (SDS) for age. However, BMI SDS can only be used as a parameter of overweight relative to the reference population and not in absolute terms, particularly if age references are regularly updated. Therefore, the International Task Force on Obesity of the WHO (ITFO) and the European childhood obesity group (ECOG) (5) suggested paediatric centiles identified by a BMI of 20, 25, and 30 in young adults as cut-offs values for the identification of underweight, overweight, and extreme overweight.

During the past two decades, a striking increase in the prevalence of obesity has occurred in Western countries, but also in fast industrializing countries and urbanized areas. In the United States, an alarming prevalence of obesity has been reported in children and adolescents (13) since the early 1980s. In the United Kingdom, a striking increase in BMI, especially that of young women, was found over the years 1973 to 1988 (14). In the Netherlands weight for height values stabilized in the period 1965-1980, and even slightly lower values at the level of the 90th, 50th, and 10th BMI centiles, (P_{90}, P_{50}, P_{10}, respectively) were found from 3 months of age onwards (15,16).

In our study, we present updated Dutch BMI reference charts, based on the fourth nation-wide growth study, performed in 1996-1997 (17). We evaluated the relations between BMI SDS and geographical region, educational level, and family structures. We compared the distribution of BMI in the populations of 1997 and 1980, to assess if the current epidemic of obesity has reached the Netherlands. In addition, the recommendations for identification of overweight children by the ITFO and ECOG were assessed on the 1997 and 1980 Dutch BMI data.

Methods

Subjects

BMI reference charts were based on a cross-sectional collection of growth data for 14,500 children (7,482 boys and 7,018 girls) of Dutch origin, measured in 1996-1997. The sample size was based on the aim to detect a 1.8 cm height difference ($p = 0.05$) between the 1997 and 1980 growth studies (with a power of 99%) (17). The sample was stratified by province, municipal size, sex, and age according to geographical distribution based on nationwide demographic data (17). The distribution of the total sample was found to be similar to national distributions, except for geographical region for girls aged ≥18 years (17). Children with non-Dutch parents, children with diagnosed growth disorders, and those on medication known to interfere with growth were excluded. In contrast to previous Dutch growth studies, infants with a birthweight below 2500 g were included.

Measurements

The measurements were standardized, and performed by trained health care professionals. Infants' length was measured to the nearest 0.1 cm in the supine position until two years of age. From 2.0 years of age, standing height was measured to the nearest 0.1 cm. Infants up to 15 months of age were weighed naked, on calibrated baby-scales. Older children were weighed, wearing underwear only, on calibrated mechanical or electronic step-scales. Weight was recorded in log steps for infants, and rounded to the nearest 0.1 kg for older children. A questionnaire, filled in by a health care professional, was used to assess demographic variables. Provinces were clustered into four geographical regions. A fifth region was formed by four cities with more than 200,000 inhabitants (Amsterdam, Rotterdam, Utrecht, and The Hague). Family size was defined by the number of children in a household (1, 2, 3, and ≥ 4). The same categories were used for birth rank. The highest completed educational level of the parents was used as an indicator of socio-economic status. The educational level of the child was determined at the time of measurement. If an adolescent of over 15 years of age had left the educational system, the highest completed education was recorded.

Statistical analysis

The distribution of BMI in a population depends on age and tends to be positively skewed. The BMI reference centiles were derived using the LMS method (18). This method summarizes the centiles by three smooth curves representing skewness (L curve), the median (M curve), and coefficient of variation (S curve). The choice of the crucial smoothing parameters for the L, M, and S-curves was made by creating local detrended QQ-plots of the SDS of the reference sample across 16 age groups. The curves were fitted as cubic splines. For boys, the effective degrees of freedom (edf) were equal to 13 (M-curve), 5 (S-curve), and 5 (L-curve), and for girls 11, 5, and 6, respectively. The percentages of children in the 1997 growth study that exceeded the 10th, 50th, and 90th centiles for BMI in 1980 were calculated (11,18), as were the percentages of 20 year old subjects who exceeded the cut-off of 20 kg/m^2, 25 kg/m^2, and 30 kg/m^2, in both the 1997 and 1980 studies. The association of demographic variables (geographical region, family size, birth rank, and educational level (child and parents), and working outdoors (parents)) with BMI was assessed by univariate and multivariate analysis (ANOVA) of BMI SDS. Mean BMI SDS was calculated separately for premenarcheal and postmenarcheal girls and the difference was assessed by Student's *t*-test.

Results

Table 1 summarizes the fitted LMS curves for BMI by age and sex. L values of 1 indicate normality and smaller values represent progressively greater skewness. The M curve is the 0 SD line or 50th centile curve for BMI. The S curve defines the coefficient of variation and multiplied by 100 it can be interpreted as a percentage. The coefficient of variation is about 8% in infancy, rising to 12-13% in adolescence.

Table 2 gives the numerical values. The distribution is very skewed. The distance between +2 and +2.5 SD lines is twice as wide as that between –2.5 and –2 SD at all ages. In general, the median (0 SD) curves for boys and girls are on very similar, although boys aged 0-1 years have slightly higher BMI values. BMI increases steeply in early life, then it declines, and eventually flattens out at 5.5 years when BMI is approximately 15.5 kg/m^2. This dip in the BMI is called the 'adiposity rebound' (6,19). The age at adiposity rebound occurs earlier on the higher than the lower centiles, with a difference of up to 2 years. After the rebound, the BMI curves increase more rapidly in girls than in boys, until the age of 20.0 years.

Table 1. LMS values for body mass index (kg/m^2) in Dutch 0-21 years olds in 1997, by age and sex.

		Boys (*n*=7417)			Girls (*n*=6960)	
Age	**L**	**M**	**S**	**L**	**M**	**S**
Months						
1.0	-0.62	14.42	0.086	-0.09	14.01	0.087
3.0	-0.38	16.13	0.081	-0.29	15.75	0.083
6.0	-0.22	17.15	0.078	-0.35	16.70	0.082
9.0	-0.15	17.44	0.077	-0.38	16.91	0.081
12.0	-0.12	17.35	0.076	-0.43	16.82	0.080
15.0	-0.09	17.12	0.077	-0.50	16.59	0.080
18.0	-0.06	16.87	0.077	-0.60	16.37	0.079
21.0	-0.03	16.62	0.078	-0.70	16.21	0.079
Years						
2.0	-0.01	16.42	0.079	-0.82	16.07	0.078
3.0	-0.07	15.89	0.084	-1.18	15.74	0.081
4.0	-0.38	15.61	0.088	-1.42	15.51	0.087
5.0	-0.85	15.52	0.093	-1.57	15.37	0.094
6.0	-1.32	15.52	0.097	-1.66	15.47	0.102
7.0	-1.70	15.61	0.101	-1.71	15.71	0.110
8.0	-1.95	15.82	0.104	-1.73	16.00	0.117
9.0	-2.08	16.10	0.107	-1.72	16.32	0.122
10.0	-2.13	16.43	0.110	-1.69	16.72	0.126
11.0	-2.10	16.83	0.112	-1.66	17.21	0.128
12.0	-2.02	17.32	0.113	-1.63	17.82	0.128
13.0	-1.93	17.90	0.114	-1.63	18.51	0.127
14.0	-1.82	18.54	0.115	-1.64	19.19	0.126
15.0	-1.71	19.21	0.115	-1.68	19.81	0.123
16.0	-1.59	19.85	0.115	-1.73	20.34	0.121
17.0	-1.47	20.43	0.115	-1.78	20.78	0.119
18.0	-1.33	20.94	0.115	-1.83	21.16	0.117
19.0	-1.18	21.37	0.115	-1.88	21.50	0.115
20.0	-1.04	21.75	0.115	-1.93	21.80	0.113
21.0	-0.90	22.11	0.115	-1.97	22.09	0.111

Table 2. Body mass index (kg/m²) values (–2 SD, 0 SD and +2 SD) in Dutch 0-21 year olds in 1997, for both sexes.

	Boys (*n*=7417)			Girls (*n*=6960)		
Age	**- 2 SD**	**0 SD**	**+2 SD**	**- 2 SD**	**0 SD**	**+2 SD**
Months						
1.0	12.2	14.4	17.3	11.8	14.0	16.7
3.0	13.8	16.1	19.1	13.4	15.8	18.7
6.0	14.7	17.2	20.1	14.2	16.7	19.8
9.0	14.9	17.4	20.4	14.5	16.9	20.0
12.0	14.9	17.4	20.3	14.4	16.8	19.9
15.0	14.7	17.1	20.0	14.2	16.6	19.6
18.0	14.5	16.9	19.7	14.1	16.4	19.3
21.0	14.2	16.6	19.4	14.0	16.2	19.1
Years						
2.0	14.0	16.4	19.2	13.9	16.1	19.0
3.0	13.5	15.9	18.8	13.6	15.7	18.8
4.0	13.2	15.6	18.7	13.3	15.5	18.9
5.0	13.1	15.5	19.0	13.0	15.4	19.2
6.0	13.1	15.5	19.4	13.0	15.5	19.9
7.0	13.1	15.6	20.0	13.0	15.7	20.7
8.0	13.3	15.8	20.7	13.1	16.0	21.6
9.0	13.5	16.1	21.4	13.3	16.3	22.4
10.0	13.7	16.4	22.1	13.6	16.7	23.2
11.0	14.0	16.8	22.8	13.9	17.2	24.0
12.0	14.4	17.3	23.5	14.4	17.8	24.9
13.0	14.8	17.0	24.2	15.0	18.5	25.7
14.0	15.3	18.5	25.0	15.6	19.2	26.5
15.0	15.8	19.2	25.7	16.1	19.8	27.2
16.0	16.3	19.9	26.4	16.6	20.3	27.8
17.0	16.8	20.4	27.1	17.0	20.8	28.3
18.0	17.1	20.9	27.6	17.4	21.2	28.7
19.0	17.4	21.4	28.0	17.8	21.5	29.0
20.0	17.7	21.8	28.3	18.1	21.8	29.3
21.0	17.9	22.1	28.6	18.4	22.1	29.6

Table 3. The mean age, BMI, and BMI SDS for premenarcheal and postmenarcheal girls, in four age groups.

	n	Age	BMI	BMI SDS	*p*
Age 11-12 yr					
Premenarche	293	11.5	17.6 (2.8)	- 0.15 (1.1)	<0.001
Postmenarche	20	11.6	20.4 (2.7)	0.90 (0.8)	
Age 12-13 yr					
Premenarche	218	12.5	18.0 (2.8)	- 0.25 (1.1)	<0.001
Postmenarche	89	12.6	20.0 (2.6)	0.55 (0.8)	
Age 13-14 yr					
Premenarche	132	13.4	17.9 (2.2)	- 0.55 (1.0)	<0.001
Postmenarche	213	13.5	20.0 (2.6)	0.29 (0.9)	
Age 14-15 yr					
Premenarche	50	14.4	18.5 (2.1)	- 0.59 (1.0)	<0.001
Postmenarche	261	14.5	20.3 (2.5)	0.19 (0.8)	

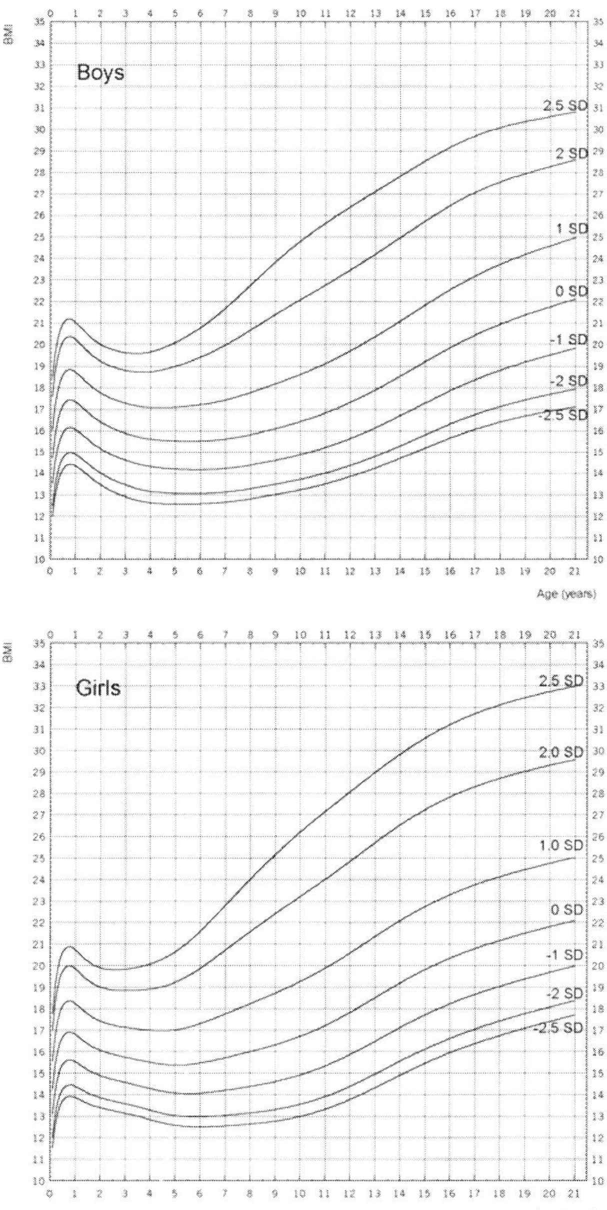

Figure 1. 1997 body mass index (BMI) reference charts, for boys and girls 0-21 years, indicating –2.5 (0.6th), -2 (2nd), -1 (16th), 0 (50th), +1 (84th), +2 (98th), and +2.5 (99.4th) SD lines and their corresponding centile values.

Figure 1 shows the reference charts that correspond to the fitted LMS values, for both sexes, including the 0, ±1, ±2, and ±2.5 SD lines and provides the corresponding centile values.

Table 3 illustrates that the mean BMI SDS is significantly greater for postmenarcheal than premenarcheal girls in all age groups. Consequently, in clinical use, one should be aware of a difference of more than 0.8 BMI SDS between premenarcheal and postmenarcheal girls (20).

Figure 2 shows the difference in the BMI distribution between the 1997 and 1980 growth studies. From 3 years of age onwards, 14-22 % exceeded the P_{90} of 1980, 52-60% the P_{50}, and 92-95 % the P_{10}. Maximal differences were found at age 6 for both sexes: over 20% exceeded the 90th centile of 1980, and more than 60% the 50th centile. The differences for the 10th centile were less obvious.

Figure 3 shows the effects of demographic variables on BMI SDS. Univariately, mean BMI was significantly related to geographical region ($p<0.0001$), educational level of the parents ($p<0.0001$), family size ($p=0.001$), educational level of the child ($p=0.017$), one or two parent families ($p=0.001$), and maternal employment ($p=0.05$). Birth rank ($p=0.085$) and working status of the father were not significantly related ($p=0.362$). Multivariately, we found an association with BMI SDS for geographical region ($p<0.0001$), educational level of the parents ($p<0.0001$), family size ($p<0.0001$), birth rank ($p<0.0001$), and the absence of the mother, illustrated by working outside the home ($p=0.019$). The effect of the presence of the mother on the BMI SDS, was supported by the positive correlation between the number of hours of outside employment and the BMI SDS ($p=0.007$). No significant association was found with the educational level of the child or one or two parent household. The effect of geographical region primarily related to large cities, which differs substantially from the rest. The relation between birth rank, family size, and BMI SDS was complicated. Children with no siblings had a relatively higher mean BMI SDS. However, within families, first born children tended to have relatively lower mean BMI SDS, and children showed increasing mean BMI SDS values with higher rank of birth.

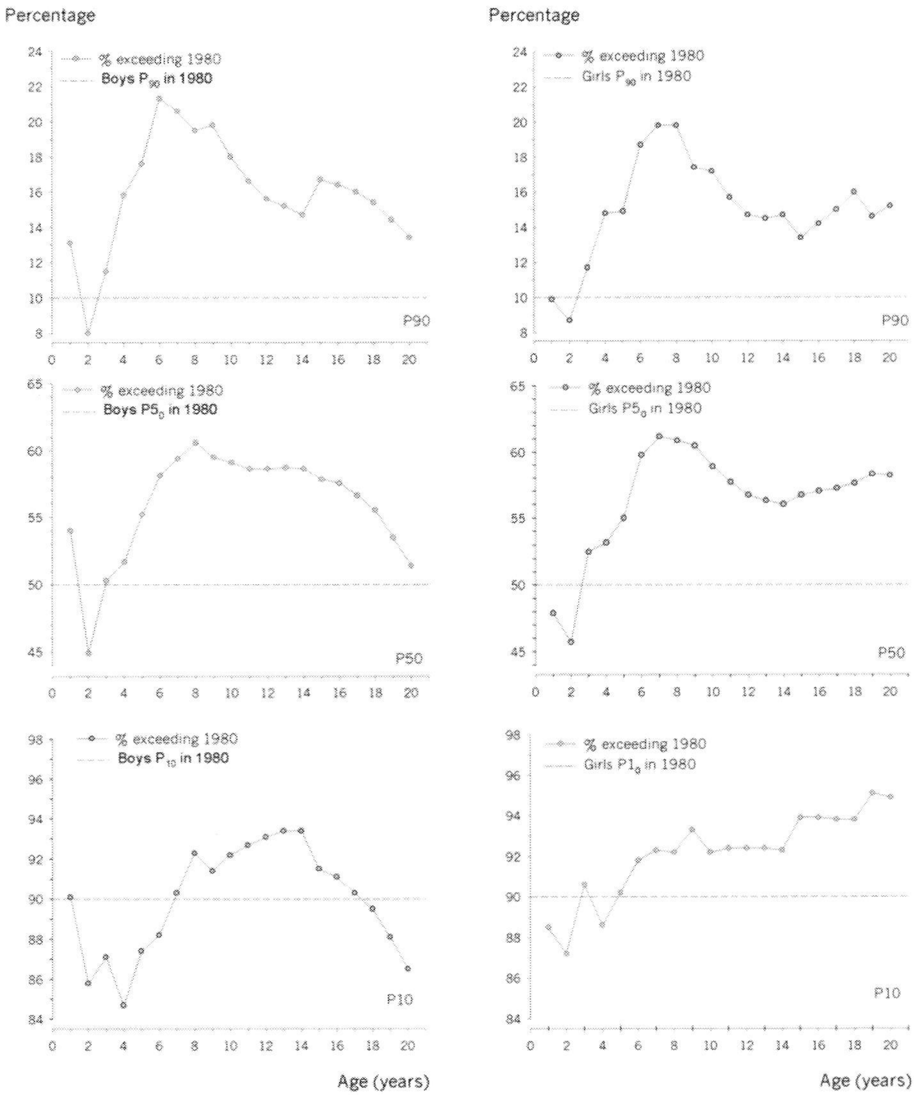

Figure 2. Percentages of boys and girls in 1997 that exceeded the P_{90}, P_{50}, and P_{10} of 1980 body mass index, 1-20 years of age.

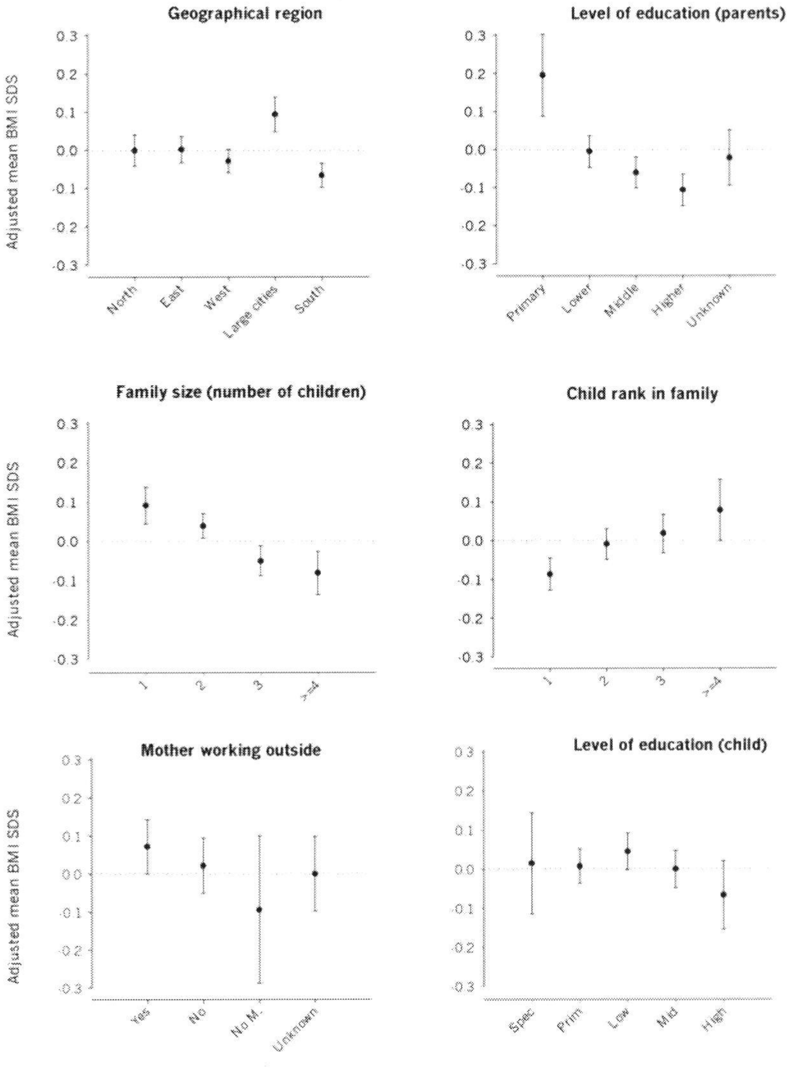

Figure 3. Mean body mass index standard deviation scores (BMI SDS) (with their 95% confidence intervals) for geographical region, level of parental and child eductation, family size, birht rank, and working status of the mother. Values are means adjusted for the effects of the other factors. For significance levels see text.

We compared the use of the cut-off values of 20, 25, and 30 kg/m^2 in young adults in the 1997 BMI distribution with the 1980 distribution, because the latter has been suggested as an international standard (11). The percentages (1980 data in parenthesis) below the centile corresponding to adult BMI of 20 kg/m^2 in 1997 were 22.3% (19.8%) for boys, and 19.7% (27.5%) for girls. Percentages exceeding 25 kg/m^2 were 13% (9.9%) and 13.7% (8.8%), and above 30 kg/m^2 they were 0.9% (0.5%) and 1.5% (0.4%), for boys and girls, respectively. When we transform these cut-off values to SD's to identify the paediatric centiles (those for 1980 in parenthesis), we found that the 20 kg/m^2 cut-off value corresponded to –0.8 SD (-0.9) for men and –0.9 SD (-0.6) for women at 20 years of age. Similarly, a BMI of 25 kg/m^2 corresponded to +1.1 SD (+1.3) and +1.1 SD (+1.4) and a BMI of 30 kg/m^2 corresponded to +2.4 SD (+2.6) and +2.2 SD (+2.7), respectively. Thus, the –0.9, +1.1, and +2.3 SD lines in the 1997 BMI charts correspond approximately to the recommended limits for underweight, overweight, and extreme overweight, respectively.

Discussion

The current increase in prevalence of youth obesity in Western countries has also occurred in the Netherlands, although during the period 1965-1980 little difference had been found in weight for height (16). Therefore, it seems that the rise in obesity has taken place since 1980. By 1997, the number of children exceeding the 1980 BMI 90th centile had almost doubled. The largest difference was observed at approximately 6 years of age, but overall the entire weight for height distribution has shifted upwards. This phenomenon corresponded to the reported positive secular change in height for age, that has also occurred mainly in childhood (17). Overweight children tend to be taller, have advanced bone-age, and mature earlier than non-overweight children, because height gain accelerates or follows shortly upon excessive weight gain (21).

Age-related BMI reference charts were constructed, based on data from the 1997 Dutch Growth Study (17). The BMI centiles rose steeply in infancy, fell during the pre-school years, and rose again from 6 years onwards to 22.1 kg/m^2 for both sexes at 21 years of age. The age at which the adiposity rebound occurs is prognostic of overweight at adulthood. The age of rebound was 6 years in 1980 (11) and changed to 5.5 years in the 1997 growth study. The earlier this age of adiposity rebound, the greater the risk of adult obesity (19,22). Although the current BMI centiles are based on a cross-sectional study, it is striking that the lower centiles rebound later, by 3 years or more, than higher centiles. A similar phenomenon was found in the United Kingdom BMI reference charts (6,7).

Weight is ultimately determined by the complex interaction of genetic (23,24), environmental, cultural, and psychosocial factors, acting through the physiological mediators of expenditure and energy intake. In general, it is assumed that the current rise in obesity is caused largely by environmental factors because genetic changes could not occur at this rate (25). Studies in the USA found no relation between the amount of physical activity and BMI in children, but higher BMI values were associated with watching more television (26,27), although other studies found no (or weaker) correlations (28,29). Furthermore, it is not clear if watching television is the cause or the consequence of being obese (28). A Dutch study found that 40% of children over 12 years of age spent more than two hours a day watching television (30). It may be that two mechanisms play a role, i.e. reduced energy expenditure as well as increased dietary intake during viewing or as a response to food advertising.

Contradictory results caused by methodological problems were also reported in studies that evaluate food consumption in obese and normal weight children (31). However, a consistent finding is that younger children with overweight parents consumed diets higher in fat than children with lean parents. A Dutch study reported that from 4 years of age onwards, children's food patterns were similar to those of their parents. Comparisons among adolescents showed that the intake of fruit juices, soft drinks and 'invisible fats' has increased over the past decade. In addition, more snacks and sweets (candy) are eaten between regular meals (32), probably stimulated by the fact that increasing numbers of children and adolescents do not eat breakfast. This was observed more often in children of poorly educated fathers and children living in large cities (33).

More overweight children were found in the four large cities studied. Therefore, we conclude that child public health care should concentrate particularly on preventing obesity in these urbanized areas in the Netherlands. In contrast to the impressive height differences between the northern and southern regions (17), no differences in BMI were observed between these regions. Raised BMI values were found in children with less well educated parents, the negative correlation with the educational level of the child disappearing in the multivariate analysis. Adult studies reported low educational level, low income, and urbanization as risk factors for raised BMI (34,35). Parental obesity strongly increases the risk of obesity, both in childhood and in adulthood (19,36,37).

The recommendation of IOTF/ECOG to extrapolate the adult cut-off values back to childhood, would result in using the –0.9, +1.1, and +2.3 SD lines as cut-off limits for underweight, overweight, and extreme overweight, respectively. Compared with the 1980 study (16), higher percentages of children were (extremely) overweight according to the proposed IOTF/ECOG classifications. The BMI value of 20 kg/m^2 for identification of underweight might be appropriate for a country such as the USA, but in the Netherlands this cut-off would result in categorizing more than 20% of children as underweight. The adult BMI cut-off value of 18.5 kg/m^2 might be more useful; this would correspond to the paediatric –1.8 SD line, and consequently 4% of children would be categorized as underweight.

Weight for height^n indices are cheap and easy to perform and calculate, and BMI (weight/height^2) is particularly useful in diagnosing overweight. Other advantages of the use of BMI in childhood are that it is widely accepted in adulthood, and that BMI charts are less affected by differences in timing of puberty than weight for height charts. However, SDS values must be used to allow for a more unbiased comparison between sexes and ages (38). In addition, it should be realized that BMI is dependent on stature (especially at younger ages) and sitting height, even though the denominator height^2 was originally intended to correct for stature. Persons with short legs have relatively higher BMI values (39). Moreover, BMI and both fat mass and fat free mass in infancy correlate poorly. In children and adolescents the correlations ranges from 0.39-0.90, depending on the method of bodyfat measurement and the age and sex of the subjects (40). In a minority of children heavy musculature can be confused with obesity.

Although obesity related morbidity is rare in childhood and adolescence, a few longitudinal studies have shown an association with increased adult morbidity and mortality (increased blood pressure, adverse lipoprotein profiles, non-insulin dependent diabetes mellitus, and atherosclerotic lesions). Depending on the applied definition of obesity, between 15 and 80% of obese children remain obese in adulthood because of tracking of their BMI. Because adverse health effects later in life may be consequent upon childhood obesity (41), we recommend obesity prevention early in life should be a priority in child public health care.

In conclusion, we found an increase of BMI for age centiles in the Netherlands, especially in childhood and adolescence, compared with 1980. Taking a BMI of 25 kg/m^2 as the limit, 13.4% of young adults were overweight. This corresponded approximately to the paediatric +1.1 SD line in the 1997 reference charts. Children in large cities, with poorly educated parents showed relatively high mean BMI SDS values. The observed rise in childhood obesity will probably result in increased adult obesity in the near future.

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Chapter 6

Are age-references for waist circumference, hip circumference, and waist-hip ratio in Dutch children, useful in clinical practice?

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Abstract

Objective To present age references for waist circumference (WC), hip circumference (HC), and waist/hip ratio (WHR) in Dutch children.
Methods Cross-sectional data were collected of 14,500 children of Dutch origin in the age range 0-21 years. National references were constructed with the LMS method. The correlations between BMI-SDS, the circumferences and their ratio, and demographic variables were assessed by (multiple) regression analysis for 3 age groups: 0-<5 years (I), 5-<12.5 years (II), and 12.5-<21 years (III). A cut-off for clinical use was suggested based on the International Obesity Task Force criteria for BMI.
Results Mean WC and HC values increased with age. Mean WC was slightly higher in boys than in girls, and this difference was statistically significant from 11 years of age onwards. In contrast, HC was significantly higher in girls than in boys from 9 years onwards. The correlation between WC SDS and BMI SDS ($r= 0.73$, $p<0.01$) and between HC and BMI SDS ($r=0.67$, $p<0.01$) increased with age. With regard to WHR SDS a low correlation was found for 12.5-20 years of age ($r=0.2$, $p<0.01$). WC SDS correlated positively with height SDS ($r=0.35$, $p<0.01$).
Conclusion Waist circumferences can be used to screen for increased abdominal fat mass in children, whereby a cut-off point of 1.3 SDS seems most suitable.

Introduction

In adults, there is abundant evidence that a predominantly central fat distribution is associated with increased risk of cardiovascular and metabolic diseases (1). Originally the waist/hip ratio (WHR) was used to estimate fat distribution, but later studies suggested that waist circumference (WC) itself was a useful measure in its own right (2-5). However, there is no consensus about the best cut-off points to be used for identifying individuals at risk. Some investigators suggested to use two cut-off points for each gender based on established cut-off points for body mass index (BMI): a waist circumference >94 cm (level I; overweight, BMI>25 kg/m^2) and >102 cm (level II; obese, BMI>30 kg/m^2) in men and for women >80 and >88 cm, respectively (2). Others proposed WC >100 cm when ≤40 years and WC >90 cm for adults >40 years, for both men and women (3). There is considerable evidence that also in children a greater deposition of central fat increases the risk of metabolic complications such as atherogenic lipoprotein profile (high LDL cholesterol and triglycerids and low HDL cholesterol), insulin resistance and corresponding high basal insulin concentrations and glucose intolerance (6-12), and high blood pressure. In addition, adiposity tracks from childhood into adulthood (13,14). Therefore, early identification and treatment of children with central adiposity is important (4).

Reference charts of WC for children are available for several countries (United Kingdom, Spain, New Zealand, United States, Italy) (4,6,15-17). Some studies assessed the validity of WC, WHR, and various indices as indicators of trunk fat mass (4,18). However, no long-term follow-up studies exist on the association between WC in childhood and adult diseases such as cardiovascular disease and metabolic syndrome. Consequently there is no direct evidence available that could be used to establish the best cut-off lines to identify children at risk.

The most common methods for diagnosing overweight and obesity are based on weight-for-height and BMI (kg/m^2). However, both measures are suboptimal markers for total body fat percentage and even less suitable to assess body fat distribution. In light of the trend of increasing percentages of overweight and obese children, and in view of the special risk of excessive abdominal fat deposition, WC may serve as an easy and direct diagnostic measure for detecting overweight and obese children at risk. Then, early detection should in turn lead to early interventions to prevent later metabolic complications in adulthood.

Hip circumference (HC) also reflects to a certain extent the body composition (i.e. muscle mass, fat mass and skeletal frame), but in childhood its prognostic value in childhood for later health risks in adulthood is limited (16). Waist/hip ratio is a measure for relative fat distribution over the body, which has been widely used in adults. Similarly to the situation with regard to waist circumference, there is no consensus about the best cut-off limits for WHR. In one study it was suggested to use high ratio ('apple' shape): 0.94 to >1.0 for men and >0.80 to >0.90 for women, since these were associated with increased risk for cardiovascular diseases and related mortality, while a lower ratio ('pear' shape) was not (19). However, in children the prognostic value of this measure appears lower to that of WC and does not accurately reflect intra abdominal fat mass (4,10). Waist for height ratio is a better predictor for visceral fat and of mortality than WHR (19).

In this paper we present reference SD curves for WC, HC, and WHR for Dutch children, aged 0-21 years, as well as the correlations with BMI SDS, height SDS and demographic variables. We also present a proposal about cut-off lines for screening overweight and obese children and adolescents in youth health care.

Methods

Subjects

Cross-sectional data on height, weight, waist circumference, and hip circumferences were collected from 14,500 children, 7,482 boys and 7,018 girls, of Dutch origin in the age range of 0-21 years in the Fourth Dutch Growth Study (1997). Children with known growth disorders and those on medication known to interfere with growth were excluded from the sample (n=108). Details have been described elsewhere (20,21). The sample is nationally representative. Anthropometric measurements were performed by trained staff and a questionnaire on demographic variables was filled in (20).

Measurements

Until two years of age, length of infants was measured in supine position, thereafter standing height was measured. Infants up to 15 months of age were weighed naked on calibrated baby-scales, older children on calibrated mechanical or electronic step-scales, wearing underwear only.

Waist circumference was measured midway between the lowest rib and the top of the iliac crest at the end of gentle expiration. Hip circumference was measured over the great trochanters. This was not necessarily the widest circumference. Circumferences were measured over the naked skin and noted to the nearest 0.1 cm. Infants were measured in supine position.

Statistical analysis

BMI was calculated as weight (kg)/height (m^2). References for WC, HC, and WHR for age were constructed with the LMS method and presented as SD lines. The distribution of the data is summarized by three spline curves, the L, M, and S, that vary in time: the

Box-Cox transformation power that converts data to normality and minimizes the skewness of the dataset (L), the median (M), and the coefficient of variation (S) (22). The choice of the smoothing factors for the L, M, and S curves was made by creating local detrended QQ plots (23). Besides WC (cm) /height (cm) the conicity index was calculated (WC/(0.109 x square root of weight/height), in which waist circumference and height were expressed in meters and weight in kg. The associations between WC SDS, HC SDS, WHR SDS, and BMI SDS and height SDS, and the association with demographic variables were calculated by (multiple) regression analyses and studied for 3 age groups: 0-<5 years (I), 5-<12.5 years (II) and 12.5-<21 years (III).

In order to determine which cut-off of WC would be best for screening purposes, we used the following strategy. We calculated for all children over 2 years of age if they were detected to be overweight or obese according the cut-off limits proposed by the International Obesity Task Force (IOTF) for BMI (24) and calculated contingency tables for WFH (weight for height) SDS, WC SDS and WHR SDS according to possible screening criteria, which means SDS >2.5 (0.5% detected for follow up), SDS >2.3 (1%), SDS >2 (2%), SDS >1.7 (5%), and SDS >1.3 (10%) to estimate the amount of misclassification for each separate screening criterion.

Results

Reference SD charts for waist circumference (WC), hip circumference (HC), BMI (including the IOTF overweight and obesity lines), and waist/hip ratio (WHR) for age were constructed for boys and girls aged 0-21 years (see Appendix 2) (25). Mean WC and HC increase in boys and girls with age and vary with gender, so separate age reference charts are necessary to evaluate an individual's position. In infancy gender differences were small, however at all ages WC was higher in boys than in girls and this difference was significant from 11 years of age onwards. Boys' curves continued to increase more sharply after this age, while girls' curves began to level off. In contrast, at all ages HC was higher in girls than in boys, and from 9 years onwards differences were statistically significant. From 16 years of age differences decreased again. Because the increase with age was relatively greater for HC than for WC, mean WHR decreased from 1.01 (0.5 yr) to 0.83 (21 yr) in boys and from 1.0 to 0.75 in girls. The reference values are shown in table 1.

Table 1. 0 en ±2 SD reference values for waist circumference (cm), hip circumference (cm), and waist/hip ratio (WHR) for boys and girls of Dutch origin in the age-range 0-21 years.

BOYS

Age	**Waist circumference**			**Hip circumference**			**WHR**		
Years	**-2 SD**	**0 SD**	**+2 SD**	**-2 SD**	**0 SD**	**+2 SD**	**-2 SD**	**0 SD**	**+2 SD**
0.25	33.0	39.4	45.4	31.6	37.3	43.9	0.899	1.041	1.196
0.50	35.9	42.0	48.0	35.5	41.4	48.3	0.885	1.013	1.152
0.75	37.4	43.4	49.5	37.6	43.4	50.4	0.879	0.998	1.128
1.0	38.3	44.3	50.6	39.1	44.7	51.6	0.875	0.988	1.111
2.0	41.1	46.9	53.7	42.9	48.5	55.6	0.869	0.968	1.077
3.0	44.0	49.7	56.9	45.5	51.4	59.0	0.866	0.962	1.070
4.0	45.5	51.2	59.0	47.8	54.2	62.5	0.849	0.945	1.053
5.0	46.3	52.1	60.7	49.8	56.7	66.0	0.827	0.923	1.032
6.0	47.2	53.3	62.9	51.5	59.0	69.6	0.810	0.905	1.015
7.0	48.4	54.8	65.5	53.2	61.3	73.2	0.796	0.891	1.002
8.0	49.7	56.5	68.5	55.3	64.2	77.5	0.784	0.878	0.990
9.0	51.0	58.2	71.4	57.8	67.4	81.7	0.773	0.866	0.978
10.0	52.3	59.9	74.3	60.2	70.4	85.2	0.763	0.855	0.966
11.0	53.8	61.8	77.2	62.4	73.3	88.4	0.755	0.846	0.957
12.0	55.4	63.9	80.0	64.7	76.3	91.7	0.748	0.838	0.949
13.0	57.2	66.1	82.8	67.4	79.8	95.5	0.741	0.831	0.942
14.0	59.1	68.2	85.2	70.7	83.7	99.1	0.735	0.825	0.937
15.0	60.9	70.3	87.4	74.2	87.1	102.0	0.730	0.821	0.933
16.0	62.6	72.3	89.4	76.9	89.6	104.0	0.729	0.820	0.934
17.0	64.1	74.0	91.1	78.6	91.3	105.4	0.729	0.821	0.936
18.0	65.4	75.6	92.6	79.8	92.3	106.3	0.731	0.824	0.941
19.0	66.6	77.0	94.0	80.6	93.1	107.0	0.733	0.827	0.946
20.0	67.7	78.3	95.4	81.2	93.6	107.5	0.735	0.831	0.951
21.0	68.8	79.6	96.6	81.6	94.1	107.9	0.738	0.834	0.956

GIRLS

Age	**Waist circumference**			**Hip circumference**			**WHR**		
Years	**-2 SD**	**0 SD**	**+2 SD**	**-2 SD**	**0 SD**	**+2 SD**	**-2 SD**	**0 SD**	**+2 SD**
0.25	32.1	38.4	44.2	31.4	36.8	43.7	0.885	1.031	1.174
0.50	35.0	41.0	47.0	35.3	41.1	48.4	0.868	0.997	1.128
0.75	36.4	42.3	48.5	37.2	43.1	50.4	0.863	0.982	1.105
1.0	37.4	43.2	49.6	38.5	44.4	51.6	0.863	0.973	1.091
2.0	40.9	46.4	53.0	42.3	48.4	55.8	0.864	0.959	1.063
3.0	43.5	49.2	56.6	45.4	52.0	60.1	0.856	0.946	1.047
4.0	44.6	50.6	58.7	47.6	54.8	63.9	0.835	0.923	1.028
5.0	45.1	51.3	60.4	49.2	57.0	67.0	0.809	0.899	1.008
6.0	45.9	52.5	62.7	51.0	59.6	70.9	0.788	0.879	0.993
7.0	47.1	54.0	65.5	53.0	62.4	75.3	0.772	0.863	0.981
8.0	48.3	55.7	68.5	55.1	65.5	80.0	0.757	0.849	0.970
9.0	49.6	57.3	71.4	57.6	69.0	85.0	0.743	0.834	0.958
10.0	50.9	59.0	74.2	59.9	72.1	89.4	0.730	0.820	0.946
11.0	52.3	60.6	76.9	62.2	75.2	93.2	0.716	0.806	0.934
12.0	53.8	62.4	79.3	65.1	79.0	97.2	0.703	0.792	0.922
13.0	55.3	64.1	81.4	68.5	83.2	101.2	0.691	0.779	0.911
14.0	56.6	65.6	83.2	71.4	86.6	104.3	0.681	0.768	0.903
15.0	57.8	66.8	84.6	73.5	89.0	106.4	0.673	0.760	0.898
16.0	58.8	67.9	85.7	74.9	90.6	107.9	0.667	0.755	0.897
17.0	59.6	68.8	86.7	76.1	91.9	109.1	0.664	0.752	0.898
18.0	60.3	69.5	87.5	77.1	93.0	110.3	0.662	0.750	0.900
19.0	60.9	70.2	88.3	77.8	93.8	111.0	0.661	0.750	0.904
20.0	61.4	70.8	88.9	77.9	93.9	111.2	0.661	0.750	0.908
21.0	61.9	71.3	89.5	78.5	94.5	111.7	0.660	0.750	0.912

The correlations between the different variables for all ages are shown in table 2. For WHR SDS the correlation with BMI SDS was low, the highest was seen in boys (r=0.13) and girls (r=0.25) over 12.5 years (p<0.01). The correlation between WC SDS and BMI SDS was relatively low in 0-<5 year olds (r= 0.55 in boys, 0.59 in girls), and considerably higher in 5-<12.5 year olds (r= 0.79 and 0.81) and ≥12.5 years (r = 0.82 and 0.77) (p<0.01). Similar but somewhat lower correlations were observed between HC SDS and BMI SD: for age group I; r= 0.63 and 0.66, for II; r= 0.75 and 0.76, and for III; r=0.72 and 0.69 (p<0.01). For WHR SDS only a low correlation was found for age group III, r=0.20. (p<0.01). The correlations between WC SDS and height SDS were much lower than those between WC SDS and BMI SDS: in group I r=0.33 in boys, 0.36 in girls, in group II r=0.43 and 0.42, and in group III r=0.34 and 0.27 (p<0.01).

Table 2. Pearson correlation coefficient between the SD of the variables BMI, weight for height, waist circumference, hip circumference, conicity index and height. All significance levels (two tailed) p <0.01 except for height SDS and weight for height p =0.79. n = 13,418-14,427.

	BMI SD	WFH SD	WC SD	HC SD	CONICITY	H SD
BMI SD	1.000	0.969	0.703	0.694	0.069	0.111
WFH SD	0.969	1.000	0.652	0.638	0.063	-0.002
WC SD	0.703	0.652	1.000	0.693	0.634	0.351
HC SD	0.694	0.638	0.693	1.000	0.207	0.425
CONICITY	0.069	0.063	0.634	0.207	1.000	0.025
H SD	0.111	-0.002	0.351	0.425	0.025	1.000

In the multivariate regression model the variance (r^2 =0.63) of BMI SDS was predicted by WC SDS (β +0.64, SE 0.024), HC SDS (β +0.32, SE 0.024) WHR SDS (β -0.14, SE 0.019), and H SDS (β -0.26, SE 0.006) in which WC was the strongest predictor (p<0.001). Predictive variables for WC SDS were BMI SDS (β +0.07, SE 0.003), HC SDS (β +0.86 SE, SE 0.003), H SDS (β +0.06, SE 0.002), WHR SDS (β +0.71, SE 0.002), and gender (β -0.014, SE 0.002, higher for males), (r^2 =0.96).

The strategy to determine which cut-off WC value would be the best for screening purposes resulted in a cut-off >1.3 SDS for overweight and >2.3 SDS to detect obesity. The first cut-off point would classify approximately 10% as overweight children, a similar percentage as detected by the IOTF cut-off lines in BMI. 6-7% of these children were classified as overweight by both BMI and WC cut-off lines, but 3-4% by only one of the two. We found significantly higher height SDS, higher WC SDS, higher WHR SDS, lower BMI SDS, higher WFH SDS, higher weight for age SDS, higher head circumference SDS, and a higher conicity index in the 'WC only group' compared to the 'BMI only group'. A WC cut-off value of >2.3 SDS was needed to classify a similar percentage of obese children as found by the BMI cut-off criterion. Of these children 0.5% was detected by both screening criteria. When we compared the group of children who would only be detected by the WC cut-off line for obesity and the group only detected by the BMI cut-off line for obesity, we found that the 'WC only group' was older and consisted of more boys. The group had also a higher height SDS, higher WC SDS, higher WH ratio SDS, higher head circumference SDS, and a higher conicity index. The 'BMI only group' had higher weight for height SDS, and higher BMI SDS (all significant at $p<0.05$). Table 3 reports the suggested cut-off points for each 1-year age group in boys and girls.

The strategy converting the cut-off points as used in adults towards SDS for young adults in our study population are shown in table 4. The lowest reported circumferences in literature (90 cm for boys and 80 cm for girls) would fit best in our population. Higher cut-off limits would mean that too many young adults at risk would remain undetected.

Table 4. According to the suggested cut-off points commonly used in adults, waist circumferences were calculated towards SDS for young Dutch adults aged 18, 19, and 21 in our study population.

Dutch boys WC (cm)	**SDS (18 yrs)**	**SDS (19 yrs)**	**SDS (21 yrs)**
90 cm	1.77	1.62	1.34
94 cm	2.12	2.00	1.75
100 cm	2.57	2.48	2.29
Dutch girls WC (cm)			
80 cm	1.36	1.29	1.16
88 cm	2.03	1.98	1.89
90 cm	2.17	2.12	2.04

Table 3. Suggested cut-off points for waist circumference for age (yrs) for boys and girls aged 2.0-21.0 years based on the IOTF cut-off criteria for overweight and obesity in the Dutch reference population.

	BOYS			GIRLS		
Age (yrs)	**Mean**	**SDS>1.3**	**SDS>2.3**	**Mean**	**SDS>1.3**	**SDS>2.3**
2.0	46.93	51.23	54.86	46.38	50.56	54.16
2.5	48.40	52.81	56.64	47.93	52.27	56.10
3.0	49.68	54.18	58.20	49.20	53.75	57.84
3.5	50.59	55.21	59.44	50.04	54.81	59.20
4.0	51.18	55.94	60.43	50.56	55.55	60.25
4.5	51.64	56.59	61.38	50.94	56.16	61.19
5.0	52.10	57.25	62.38	51.34	56.80	62.19
5.5	52.64	58.02	63.52	51.85	57.58	63.38
6.0	53.28	58.91	64.84	52.50	58.53	64.79
6.5	54.01	59.91	66.31	53.25	59.60	66.36
7.0	54.79	60.98	67.87	54.04	60.72	68.01
7.5	55.61	62.12	69.53	54.86	61.86	69.70
8.0	56.46	63.27	71.23	55.68	63.00	71.40
8.5	57.31	64.43	72.91	56.49	64.14	73.11
9.0	58.16	65.58	74.56	57.31	65.26	74.79
9.5	59.02	66.74	76.22	58.14	66.36	76.40
10.0	59.91	67.90	77.83	58.96	67.45	77.98
10.5	60.83	69.08	79.43	59.79	68.51	79.47
11.0	61.80	70.30	81.00	60.64	69.57	80.91
11.5	62.82	71.56	82.57	61.51	70.62	82.28
12.0	63.88	72.82	84.06	62.38	71.65	83.58
12.5	64.96	74.08	85.48	63.25	72.66	84.81
13.0	66.06	75.34	86.86	64.08	73.58	85.86
13.5	67.16	76.56	88.12	64.85	74.44	86.83
14.0	68.24	77.75	89.30	65.57	75.23	87.71
14.5	69.31	78.89	90.41	66.23	75.93	88.46
15.0	70.33	79.97	91.40	66.82	76.57	89.12
15.5	71.32	81.00	92.34	67.37	77.14	89.71
16.0	72.27	82.00	93.25	67.87	77.67	90.28
16.5	73.16	82.92	94.07	68.33	78.16	90.80
17.0	74.01	83.79	94.86	68.75	78.61	91.26
17.5	74.80	84.62	95.59	69.15	79.02	91.68
18.0	75.56	85.41	96.30	69.51	79.42	92.11
18.5	76.28	86.17	97.01	69.86	79.78	92.50
19.0	76.98	86.89	97.65	70.17	80.12	92.85
19.5	77.65	87.60	98.31	70.47	80.44	93.18
20.0	78.31	88.29	98.91	70.76	80.73	93.48
20.5	78.96	88.97	99.54	71.03	81.03	93.82
21.0	79.60	89.62	100.13	71.30	81.31	94.10

Discussion

This study provides reference SD charts for waist circumferences, hip circumference and waist/hip ratio for age for a large and representative sample of Dutch boys and girls between 0-21 years. Our results indicate that compared to the other two indicators WC has a strong correlation with BMI. Furthermore, using a waist circumference above 1.3 SDS gives a reasonable approximation of overweight as defined according the international BMI cut-off values.

The American Bogulesa study (16) found similar WC values between 5-7 years of age, and somewhat higher values from 8 years onwards to 17 years in both American boys and girls. However, these differences for girls quickly decreased after age 16. Compared to a Spanish study, WC in Dutch children was lower in boys aged 4-14.9 years, and the differences increased with age to a maximum of 4 cm. For girls a similar phenomenon was seen (15). Spanish children had higher BMI references values and lower mean heights for age (26). Dutch WC mean values were comparable with British data from 1977 (boys, 11 to 17 years) and for girls with data from 1986, and were lower than British WC values measured in 1997 (6). For BMI similar results were found.

The prevalence of overweight in the Netherlands has doubled over the last 20 years. For WC no Dutch data were available until now. In Spain and the United Kingdom (6,27) the secular increase in waist circumference greatly exceeded the secular trend of BMI, especially in girls. Consequently the British group concluded that the prevalence of obesity has been systematically underestimated in 11-16 year old British children (6). This suggests that the accumulation of central body fat has risen more steeply than total body mass as derived from height and weight. In other words, the increase in the prevalence of overweight and obesity may have been underestimated, as BMI fails to distinguish between muscle and fat, and BMI seems therefore a poor proxy for central fatness (6). We assume that a similar process have occurred in the Netherlands. Waist circumference, rather than BMI, could therefore be a better candidate for acting as a screening instrument. Especially when one considers the special role that abdominal fat appears to play as a risk factor for later metabolic and heart disease, and the ease with which WC can be measured in preventive health programs. It is also a good instrument to monitor the prevalence of (central) obesity over time. Therefore WC should certainly be included in future growth studies.

There are several advantages of WC circumference measurement compared to BMI and WHR i.e.: 1) WC is relatively easy to perform; 2) it is easy to instruct, so subjects can measure themselves (28); and 3) WC predicts mortality better than other anthropometric measures because of the association with BMI, fat distribution, and metabolic abnormalities (8). BMI can provide a general description of adiposity characteristics in a healthy paediatric population, but it is less accurate in predicting fatness in an individual child (29). A longitudinal study in 8 year olds showed that WC was the best predictor for overweight at the age of 12 years, but more longitudinal studies from young childhood to young adulthood are necessary (30).

As mentioned above, one of the advantages of WC is that children can measure it themselves. The studied validity of self reported circumferences in adults is reasonable (2). There was only a slight overestimation of waist girths and underestimation of hip girths when self-measurement was compared with technician measurement. The within-person correlation between two measurements was 0.96 for WC and 0.93 when self-measurement in adult women was compared with technician measurement. The within-person variation in WC measurement increased as WC increased (31).

Before WC can be used as a screening instrument in youth health care, a rational cut-off line for an increased risk is needed. We found that the correlation between BMI SDS and WC SDS increases with age from 0.57 to 0.8. Ideally, we should have prospective studies in order to determine appropriate cut-off values for identifying children at risk data on metabolic abnormalities and high fat mass. When these are lacking, a strategy comparing a reference group and a disease group might be used (32). Such design enables to calculate both sensitivity and specificity, as well as the median detection times. For screening purposes, we will usually strive for cut-off values with a high specificity, e.g. > 99%. A cross-sectional study by an Italian group (17) found that prepubertal children with a WC over 90th percentile were more likely to have multiple risk factors than children with a WC below the 90th percentile. Their conclusions were based on the relationship between WC and lipid concentrations and blood pressure. In a Spanish study the screening performance for BMI and WC were studied based on total body adiposity. Both measurements were highly correlated to total fat percentage. A WC above the 70th percentile was recommended as cut-off for abnormal metabolic variables based on ROC analyses (sensitivity 76%, specificity 81%) (18,27). Using a similar method with ROC curves a study in New Zealand (children aged 3-19 years) found that a WC above the 80th percentile best correlated with high trunk fat mass measured by dual energy X-ray absorptiometry. WC (sensitivity 88%, specificity 93%) was a significantly better predictor than WHR (4). A study in the United Kindom recently used the cut-off points of 91st centile and the 98th centile (SD 1.33 and 2) to define overweight and obesity, based on body mass index and waist circumference separately (6). Based on the approaches described in this paper, we suggest a cut-off value for WC of 1.3 SDS for screening overweight and of 2.3 SDS for obesity in cases where direct measures of abdominal fat are not available.

WHR is generally considered a good tool to distinguish between the different types of fat distribution because it is highly correlated with visceral fat and plasma lipid concentrations. WHR showed negative associations with HDL and positive associations in the ratio total cholesterol /HDL in pre- and postpubertal girls (10). The decrease of WHR with age, especially in girls, is due to increase in pelvic diameter and predominant fat deposition in the gluteal area (33). Waist/hip ratio correlates with intra-abdominal fat, but higher correlations were found for WC (33). One of the disadvantages of WHR is that a reduction in weight usually results in a reduction in both WC and HC, so that WHR may not decrease despite the leaner body composition. In addition, a decrease in WHR may not be related to a reduction in cardiovascular risk factors (19). All in all it appears that WHR is less useful for identifying children at risk.

In a Japanese study waist-height ratio was proposed as the best predictor of cardiovascular risk and metabolic risk factors in schoolchildren (34). This result was found earlier in adults, when waist to height was suggested to be the best simple anthropometric predictor of visceral fat and a better predictor of morbidity and mortality than WHR and WC (19,35). A disadvantage is that waist to height is a ratio whereby height is inversely associated with morbidity/mortality independently of fat distribution. In addition WC is only weakly correlated with height, so there is a minimal need to adjust waist for height (19).

It is likely that in the Netherlands, like in other industrialized countries such as the United Kingdom, a further increase of the prevalence of overweight and obesity will occur. Because of the risk of future morbidity, particularly due to accumulation of excess central fat, an active preventive campaign in the Netherlands would be of great importance. It would also be advisable to monitor WC in groups with known high prevalences of overweight and obesity, such as certain ethnic groups and children living in urban areas (Fredriks *et al.* submitted).

In conclusion, we present the first Dutch reference charts for WC, HC and WHR. For practical purposes, waist circumference seems to be the most useful parameter to assess overweight in children, and a cut-off limit of 1.3 SDS appears most suitable.

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Chapter

7

Height, weight, body mass index, and pubertal development references for children of Turkish origin in the Netherlands.

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Abstract

Objectives To provide growth and sexual maturation reference data for Turkish children living in the Netherlands. We also compared these references with the reference data of children of Dutch origin and with Turkish reference data collected in Turkey and elsewhere in Europe.

Method Cross-sectional growth and demographic data were collected from 2,904 children of Turkish origin and 14,500 children of Dutch origin living in the Netherlands in the age range 0-20 years. Growth references for length, height, weight, weight for height, body mass index (BMI) and head circumference were constructed with the LMS method. Predictive variables for height and BMI were assessed by univariate and multivariate regression analyses. Reference curves for sexual maturation and menarche were estimated by a generalized additive model.

Results Young Turkish adults were 10 cm shorter than their Dutch contemporaries. Mean height was 174.0 cm for males, and 160.7 cm for females. Height differences in comparison with Dutch children started at 3 years. Height SDS was predominantly associated with target height. The height of Turkish children living in the Netherlands was similar to Turkish children in Germany and to children from high socio-economic classes in Istanbul. Compared to Dutch children, maturation stages started 0.5-0.7 years later for both sexes but the progression through puberty was faster. In girls median age at menarche was 12.8 years, 5 months earlier than in Dutch girls. BMI of Turkish children was higher than that of Dutch children at all ages. BMI SDS was associated with birthweight and the duration of stay of the mother in the Netherlands.

Conclusions Turkish children are considerably shorter and more overweight than Dutch children. Separate growth charts for Turkish children in the Netherlands are useful for growth monitoring.

Height, weight, body mass index, and pubertal development references for children of Turkish origin in the Netherlands.

Introduction

For optimal growth monitoring, up-to-date reference growth data on representative samples from the population are necessary. In a country of immigration like the Netherlands, the dilemma is whether one should use growth references derived from a representative sample from the whole (multiethnic) population or a growth reference for the ethnic Dutch population and appropriate reference data on the largest ethnic groups living in the Netherlands. One of the disadvantages of the first option is that the reliability and efficiency of growth monitoring would decrease, because children with a growth disorder of a relatively tall subpopulation would more often be considered normal versus the multiethnic reference, while children with a growth disturbance from a relatively short subpopulation would be overdiagnosed (1). Furthermore, the secular trend could not be studied anymore. Disadvantages of the second option are that there would be more than one growth reference in the country and that it would be impossible to provide specific reference data for all ethnic groups. Besides, within ethnic groups the composition of the population changes continuously through new immigrations and intermarriage.

During the preparation of the last Dutch growth study (the fourth nation-wide study in 1997) it was decided to use the same inclusion and exclusion criteria as the previous studies. This resulted in the publication of updated growth references for children of Dutch descent (2). In addition we collected growth data from the two largest ethnic minority groups living in the Netherlands, who were obviously shorter, the Turkish and the Moroccans. At this moment 35% of the first and 80% of the second generation are under 20 years of age (3). A so called 'third generation', with both parents born in the Netherlands, is still very small because the second generation is mainly younger than 20 years, and most marriages continued to take place with partners from Turkey (4).

In this paper we present the reference data on length/height, weight for height, body mass index (BMI=kg/m^2), head circumference, and sexual maturation for Turkish subjects aged 0-20 years living in the large cities in the Netherlands, collected in 1997. Height and maturation references are compared with the 1997 Dutch data and with available references of Turkish children in Turkey (5-10), Germany (11), and Sweden (12). We also investigated the association between demographic variables and these measures.

Subjects and Methods

Length, height, weight, and head circumference were cross-sectionally measured in 2,904 children of Turkish origin living in the largest four cities in the Netherlands: Amsterdam, Rotterdam, Utrecht, and The Hague. From 9 years of age (863 boys and

780 girls), pubertal stages were determined by trained staff. The analysis of sexual maturation is based on a sample of 118 boys (14%) and 108 girls (14%) and 428 girls (55%) answered the question about menarche. Children were included if both biological parents were born in Turkey. Children with diagnosed growth disorders and those on medication known to interfere with growth were excluded from the sample (n=23).

Until 4 years of age, measurements were performed during the regular periodical health examinations by instructed health professionals in the Well Baby Clinics. From 4 years onwards all Turkish children in a school class were measured during regular preventive health assessments in Municipal Health Services (at mean ages 5.5 and 7.5 years). From 9 years of age, children received a personal invitation based on a stratified sample from the Municipal Register Office, additional measurements took place at randomly selected secondary schools from different socio-economic neighbourhoods, at colleges and universities (2). In the same 1997 Dutch Growth Study, growth data of 14,500 children of Dutch origin were similarly collected over the country, including 1,505 in the large cities (2).

Measurements

Until 2 years of age, the length of infants was measured in a supine position thereafter standing height was measured. Infants up to 15 months of age were weighed naked on calibrated baby-scales, older children on calibrated mechanical or electronic step-scales, wearing underwear only. Pubertal stages were determined according to the definitions described by Tanner (13), extended by a sixth stage for pubic hair (14). The age at menarche was determined by asking each girl when she had had her first period.

A questionnaire, completed by a health professional, was used to assess demographic variables. Duration of maternal residence in the Netherlands was divided into <6, 6-<11, 11-<20 and ≥20 years. The educational level of the child was determined at the time of measurement. If an adolescent of >15 years of age had left any educational system, the highest completed education was recorded. As an indicator of socio-economic status (SES) the highest completed educational level of the parents was used. Other variables were family size (the number of children in a household), target height, the working status of parents, one or two parent families, and in the group 0-<5 years if the mother breastfed her child and smoked or consumed alcoholics during pregnancy. Birthweight and parental height were obtained by questioning the parents themselves. For the older children this was asked for in the personal invitation letter. Relationships between demographic variables and height and BMI SDS are described for both the Turkish and the Dutch group.

Statistical analysis

Reference standard deviation (SD) curves for height, weight, BMI, head circumference for age, and weight for height were estimated by the LMS method (15). The choice of the smoothing parameters for the L, M, en S-curves was made by creating local detrended QQ-plots (quantile quantile plots, special plots to compare distributions) (16) of the SDS of the reference sample. Reference curves for menarche and the stages of secondary sex characteristics were estimated by generalized additive models (17). Except for menarche, only P_{50} values could be calculated, as the more extreme P values were not sufficiently reliable because of insufficient numbers of children.

The association between demographic variables and height SDS and BMI SDS were assessed by univariate and multivariate regression analyses. The influence of a demographic variable can differ according to age or gender. Therefore we used three age groups (0-<5, 5-<12.5, and ≥12.5 years) and both age and gender were included into the regression analyses (covariates). The difference in distribution of the demographic variables over the three age groups was calculated by a chi squared test. Target height was calculated by the formula according to Tanner (paternal height + maternal height ± mean difference between male and female)/2 + secular trend. The mean height difference between Turkish parents (11.4 cm) and between Turkish boys and girls of 20 years (13.3 cm) were close to the mean height difference of ±13 cm between men and women observed in the Dutch data and most growth studies. We estimated the average secular trend in one generation (more than 50% age had their first pregnancy at 21 years) (18) as the difference between mean height of Turkish 20-year-olds and recorded parental heights in this study (2.9 cm for men, 1 cm for women). The adapted target height (TH) formula for Turkish children was thus: (paternal height + maternal height ± 13)/2 +2 cm. TH SDS was calculated as follows: (TH-mean Turkish height at 20 years of age) /SD at 20 years of age.

Results

Table 1 contains descriptive information for the Turkish and the Dutch sample on demographic variables and parental heights in three age groups. Based on data of the Turkish children's age and the duration of stay of the mother in the Netherlands we calculated that 11.3% was first, and 58.6% second generation. In 31.1% this could not be determined. According to national statistics, 11% is first and 88% is second generation under 20 year of age (19). The distribution of parental and child education, family size, working status of the parents, and one or two parent families was relatively close to available national minority statistics (20,21). On average 16% of the mothers worked, independent of the age group of the child. With respect to the other variables the distribution of the demographic variables was dependent of age.

Table 1. Percentage and total number of children from Turkish and Dutch origin for demographic variables per age group (0-<5 years, 5-<12.5 years, and ≥12.5 years). Significant differences between the three Turkish age groups are marked.

M=mother, F=father, **p*< 0.0001,~ no data available.

	0-<5 y		**5-<12.5 y**		**≥12.5 y**	
	Turkish	**Dutch**	**Turkish**	**Dutch**	**Turkish**	**Dutch**
Duration of stay M*	(*n*=882)		(*n*=957)		(*n*=954)	
<6 yr	31.9	~	6.7	~	12.6	~
6-10 yr	28.6	~	23.2	~	10.0	~
11-20 yr	26.8	~	52.0	~	51.4	~
≥20 yr	12.8	~	18.1	~	26.1	~
Educ. level child	(*n*=939)	(*n*=5739)	(*n*=968)	(*n*=3340)	(*n*=932)	(*n*=5335)
Prim. education	~	~	97.6	94.8	9.1	2.7
Lower sec education	~	~	0.7	1.3	69.0	45.0
Middle sec education	~	~	0.4	1.8	18.3	40.3
Higher sec education	~	~	~	~	1.5	10.1
Spec. education	~	~	1.2	2.1	2.1	1.9
Educ. level parents*	(*n* =580)	(*n* =5613)	(*n* =932)	(*n* =3174)	(*n* =883)	(*n* =4001)
None/primary	49.4	0.3	72.1	2.3	82.2	2.5
Lower sec education	30.3	18.8	15.9	33.0	9.7	36.9
Middle sec education	16.9	40.9	9.8	32.2	6.6	29.3
Higher sec education	3.4	39.9	2.3	32.5	1.5	31.3
Familysize*	(*n*=695)	(*n*=5732)	(*n*=976)	(*n*=3362)	(*n*=988)	(*n*=5401)
1-2	67.6	81.4	33.2	60.2	18.2	67.2
3-4	27.5	17.2	53.5	37.3	54.5	29.8
≥5	4.9	1.3	13.3	2.2	27.3	3.0
Working M outside	15.9	58.5	17.8	53.6	15.9	58.9
	(*n* =666)	(*n*=5670)	(*n* =966)	(*n* =3183)	(*n*=928)	(*n*=4910)
Working F outside*	66.2	97.4	63.0	94.4	51.3	92.7
	(*n* =575)	(*n*=5590)	(*n*=902)	(*n*=2454)	(*n*=866)	(*n*=3702)
Two parent family*	96.8	97.6	92.4	93.6	91.2	87.4
	(*n*=689)	(*n*=5735)	(*n*=972)	(*n*=3353)	(*n*=937)	(*n*=5388)
Mean height M	159.4	169.2	159.7	168.3	160.0	168.1
	(*n*=533)	(*n*=5596)	(*n*=793)	(*n*=3288)	(*n*=657)	(*n*=4788)
Mean height F *	172.7	182.3	170.6	181.1	170.6	180.5
	(*n*=449)	(*n*=5511)	(*n*=760)	(*n*=3221)	(*n*=660)	(*n*=4744)
Smoked in pregnancy	18.6	23.1	~	~	~	~
	(*n*=629)	(*n*=5499)				
Alcohol in pregnancy	0.3	16.7	~	~	~	~
	(*n*=630)	(*n*=5491)				
≥ 2 weeks Breastfed	90.0	69.0	~	~	~	~
	(*n*=671)	(*n*=5480)				

Length, weight, and head circumference from 0 to 1 year

Table 2 shows length, weight, and head circumference for 3-60 weeks old Turkish boys and girls. For a given age, length and head circumference had an approximate normal distribution but weight was skewed. Until 24 weeks of age, Turkish boys were approximately 0.5 cm smaller, thereafter on average 0.5 cm longer than Dutch boys. For girls the maximal difference was 0.2 cm. From 4 weeks of age onwards Turkish infants were 0.1 kg heavier than Dutch infants, increasing to 0.6 kg at 60 weeks (boys mean difference of 0.3 kg, girls of 0.5 kg). Head circumferences were approximately similar to Dutch infants.

Height for age from 1 to 20 years

In figure 1 the Turkish 0 and ±2 SD lines are shown, in comparison to the Dutch 0 and ±2 SD lines (2). At one year of age, Turkish infants were slightly longer than Dutch infants. From 3 years of age onwards, and for boys slightly earlier, height differences between the Dutch and Turkish population were apparent and approximately 5 cm (50% of the final difference) was achieved during childhood. In prepuberty (3-10 years) on average 13.6% boys and 7.8% girls had heights below the Dutch –2 SD lines for height and 4.1% and 1.3%, respectively, below the Dutch –2.5 SD line.

During puberty the height difference increased by another 5 cm, so that the difference with mean height of Dutch 20-year-olds further increased to 10 cm, approximately 1.5 SD in the Dutch reference diagrams. Mean final height for boys was 174.0 cm (Dutch 184.0 cm) and for girls 160.7 cm (Dutch 170.6 cm). The additional loss during puberty may be explained by a faster progression through pubertal stages (see below). For growth monitoring purposes reference charts for Turkish boys and girls for length/height, weight for height, body mass index, and sexual maturation were produced for 1- 20 years of age (22, see also Appendix 2).

Table 3 shows height, weight and body mass index (BMI) references for the age group 1-20 years for both Turkish sexes.

Table 2. Reference data (0 SD, SD and ±2 SD, when appropriate) for length, weight, and head circumference for boys and girls of Turkish origin living in the Netherlands in the age-range 3.0-60.0 weeks in the 1997 Dutch Growth Study.

				Boys			
Age	**Length**			**Weight**		**Head**	
wk	**Mean**	**SD**	**-2SD**	**0SD**	**+2SD**	**Mean**	**SD**
3.0	53.0	2.0	3.1	4.0	5.0	37.0	1.1
4.0	53.8	2.0	3.4	4.4	5.5	37.8	1.1
6.0	55.2	2.1	3.7	4.8	6.0	38.5	1.1
8.0	56.7	2.1	4.1	5.2	6.5	39.3	1.1
10.0	58.2	2.1	4.4	5.6	6.9	40.1	1.1
12.0	59.6	2.1	4.7	5.9	7.4	40.8	1.1
14.0	61.0	2.1	4.9	6.3	7.9	41.4	1.1
16.0	62.3	2.1	5.2	6.6	8.3	42.0	1.1
18.0	63.6	2.2	5.5	7.0	8.7	42.5	1.1
20.0	64.8	2.2	5.7	7.3	9.1	42.9	1.1
22.0	65.9	2.2	6.0	7.6	9.5	43.4	1.1
24.0	67.0	2.2	6.2	7.9	9.8	43.8	1.1
26.0	68.0	2.2	6.4	8.1	10.2	44.1	1.1
28.0	68.9	2.2	6.6	8.4	10.5	44.5	1.1
32.0	70.6	2.2	7.0	8.9	11.1	45.0	1.1
36.0	72.1	2.3	7.3	9.3	11.7	45.5	1.1
40.0	73.4	2.3	7.6	9.7	12.2	45.9	1.1
44.0	74.7	2.4	7.9	10.1	12.6	46.3	1.1
48.0	75.9	2.4	8.2	10.4	13.1	47.0	1.2
56.0	78.1	2.6	8.6	11.0	13.8	47.3	1.2
60.0	79.1	2.7	8.9	11.3	14.2	47.5	1.2

				Girls			
Age	**Length**			**Weight**		**Head**	
wk	**Mean**	**SD**	**-2 SD**	**0 SD**	**+2SD**	**Mean**	**SD**
3.0	52.7	2.2	3.0	4.0	4.9	37.0	1.1
4.0	53.4	2.3	3.1	4.2	5.2	37.3	1.1
6.0	54.7	2.3	3.4	4.5	5.6	38.0	1.1
8.0	56.1	2.4	3.6	4.9	6.0	38.6	1.2
10.0	57.4	2.4	3.9	5.2	6.5	39.2	1.2
12.0	58.6	2.5	4.1	5.5	6.9	39.8	1.2
14.0	59.8	2.5	4.4	5.9	7.3	40.3	1.2
16.0	60.9	2.5	4.6	6.2	7.7	40.8	1.2
18.0	62.0	2.6	4.8	6.5	8.1	41.2	1.2
20.0	63.1	2.6	5.1	6.7	8.4	41.7	1.2
22.0	64.1	2.6	5.3	7.0	8.8	42.1	1.2
24.0	65.1	2.6	5.5	7.3	9.1	42.4	1.2
26.0	66.1	2.7	5.7	7.5	9.4	42.8	1.2
28.0	67.0	2.7	5.9	7.8	9.7	43.1	1.2
32.0	68.7	2.7	6.2	8.2	10.3	43.7	1.2
36.0	70.2	2.7	6.5	8.6	10.8	44.2	1.2
40.0	71.5	2.8	6.8	9.0	11.2	44.7	1.2
44.0	72.8	2.8	7.1	9.3	11.7	45.1	1.3
48.0	75.2	2.8	7.5	9.9	12.4	45.8	1.3
56.0	76.2	2.9	7.8	10.2	12.8	46.1	1.3
60.0	74.0	2.8	7.3	9.6	12.1	45.5	1.3

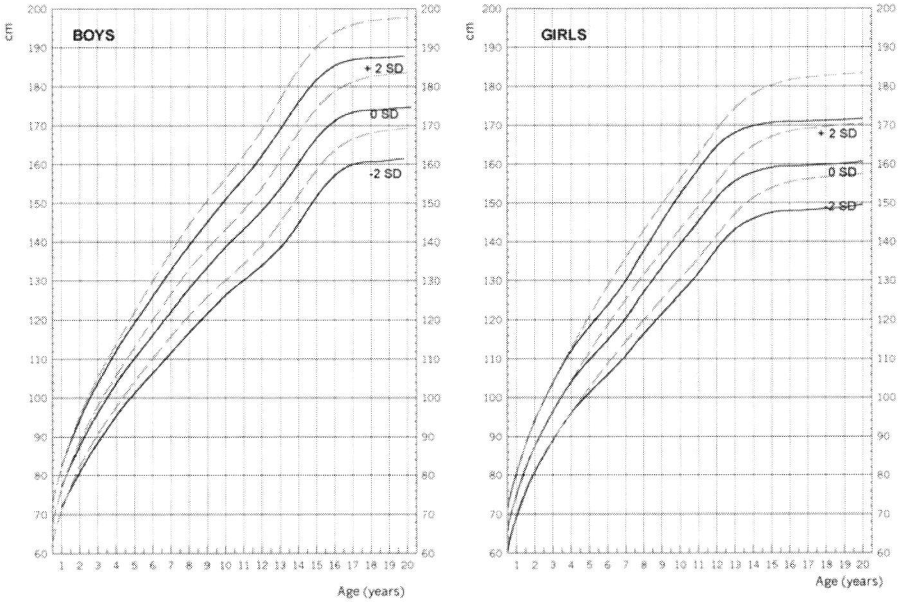

Figure 1. 0 SD (mean) and ±2 SD height reference lines for Turkish (solid) and Dutch (dotted) boys and girls in the age range 1-20 years, based on the 1997 Dutch Growth Study.

Table 3. Reference data (0 SD, SD, and ±2 SD, when appropriate) for length (1 year of age, cm), height (cm), weight (kg), and BMI (kg/m^2) for boys and girls of Turkish origin in the Netherlands, in the age range 1-20 years in the 1997 Dutch Growth Study.

		Boys						
Age	**Height**			**Weight**			**BMI**	
Yr	**Mean**	**SD**	**-2SD**	**0SD**	**+2SD**	**-2SD**	**0SD**	**+2SD**
1.0	75.2	2.8	7.5	9.9	12.4	14.3	17.3	21.0
2.0	87.6	3.3	9.9	12.9	16.4	13.8	16.8	20.7
3.0	96.6	3.7	11.9	15.5	20.0	13.6	16.6	20.7
4.0	104.1	4.0	13.7	17.9	23.5	13.5	16.5	20.9
5.0	109.9	4.2	14.9	19.7	26.3	13.2	16.4	21.1
6.0	114.9	4.5	16.1	21.5	29.4	13.1	16.3	21.4
7.0	120.6	4.8	17.6	23.8	33.5	13.1	16.5	22.1
8.0	127.1	5.3	19.5	26.9	39.4	13.3	16.9	23.1
9.0	133.4	5.9	21.7	30.8	47.4	13.6	17.5	24.4
10.0	139.5	6.4	24.1	35.4	56.3	14.0	18.2	25.9
11.0	145.3	6.7	26.7	40.4	64.5	14.5	18.9	27.5
12.0	151.3	6.6	30.3	45.5	71.7	15.1	19.7	29.1
13.0	155.7	6.3	34.5	50.2	77.8	15.7	20.5	30.5
14.0	157.9	6.0	38.1	53.7	82.4	16.2	21.1	31.9
15.0	159.2	5.8	40.5	55.9	85.7	16.7	21.7	33.1
16.0	159.5	5.8	42.0	57.2	87.6	17.1	22.2	34.1
17.0	159.7	5.7	42.8	58.0	88.6	17.5	22.6	35.1
18.0	159.9	5.7	43.3	58.3	89.2	17.8	23.0	36.0
19.0	160.2	5.6	43.5	58.6	89.5	18.1	23.4	36.9
20.0	160.7	5.5	43.8	58.8	89.8	18.4	23.8	37.8

Table 3 continued

	Girls							
Age	**Height**		**Weight**			**BMI**		
yr	**Mean**	**SD**	**-2SD**	**0SD**	**+2 SD**	**-2SD**	**0SD**	**+2SD**
1.0	77.3	2.6	8.1	10.2	12.8	15.1	17.8	21.4
2.0	88.0	3.3	10.4	13.0	16.4	14.5	17.0	20.8
3.0	97.1	3.7	12.1	15.2	19.3	14.0	16.5	20.5
4.0	104.8	4.1	13.8	17.4	22.4	13.8	16.3	20.6
5.0	111.5	4.5	15.5	19.8	25.9	13.6	16.3	21.0
6.0	117.6	4.8	17.4	22.4	29.8	13.7	16.4	21.7
7.0	122.8	4.9	19.3	25.0	34.0	13.7	16.6	22.5
8.0	128.1	5.0	21.2	27.9	38.6	13.9	17.0	23.5
9.0	134.1	5.3	23.2	30.8	43.5	14.1	17.4	24.5
10.0	138.9	5.8	25.2	33.8	48.6	14.3	17.8	25.5
11.0	143.4	6.5	27.4	37.2	54.3	14.6	18.3	26.5
12.0	149.1	7.3	30.0	41.5	60.8	15.0	18.8	27.5
13.0	156.3	7.8	33.3	46.8	68.3	15.4	19.4	28.5
14.0	163.4	7.7	37.6	52.9	76.1	15.8	20.0	29.5
15.0	167.9	7.1	42.5	58.8	82.8	16.2	20.6	30.4
16.0	170.8	6.5	47.0	63.8	87.7	16.6	21.2	31.2
17.0	172.5	6.1	50.7	67.4	91.1	17.0	21.8	31.9
18.0	173.3	5.9	53.4	70.1	93.4	17.3	22.2	32.5
19.0	173.5	5.9	55.4	72.0	95.1	17.5	22.7	33.1
20.0	174.0	5.8	57.2	73.7	96.5	17.8	23.1	33.6

Figure 2 shows mean heights of Turkish children in the Netherlands in comparison with available Turkish references in Turkey (6,9,23) and Germany (11). Heights of children of Turkish origin in the Netherlands were quite similar to Turkish children in Germany and children of high SES in Istanbul (6,24). Boys in the lowest SES group in Istanbul, from various social levels in Ankara (9) and of high SES in Trabzon (Eastern Black Sea urban region) (23), were slightly shorter. In contrast, Turkish children in Sweden were slightly shorter than those of high SES children in Istanbul (12). For girls, we observed similar findings.

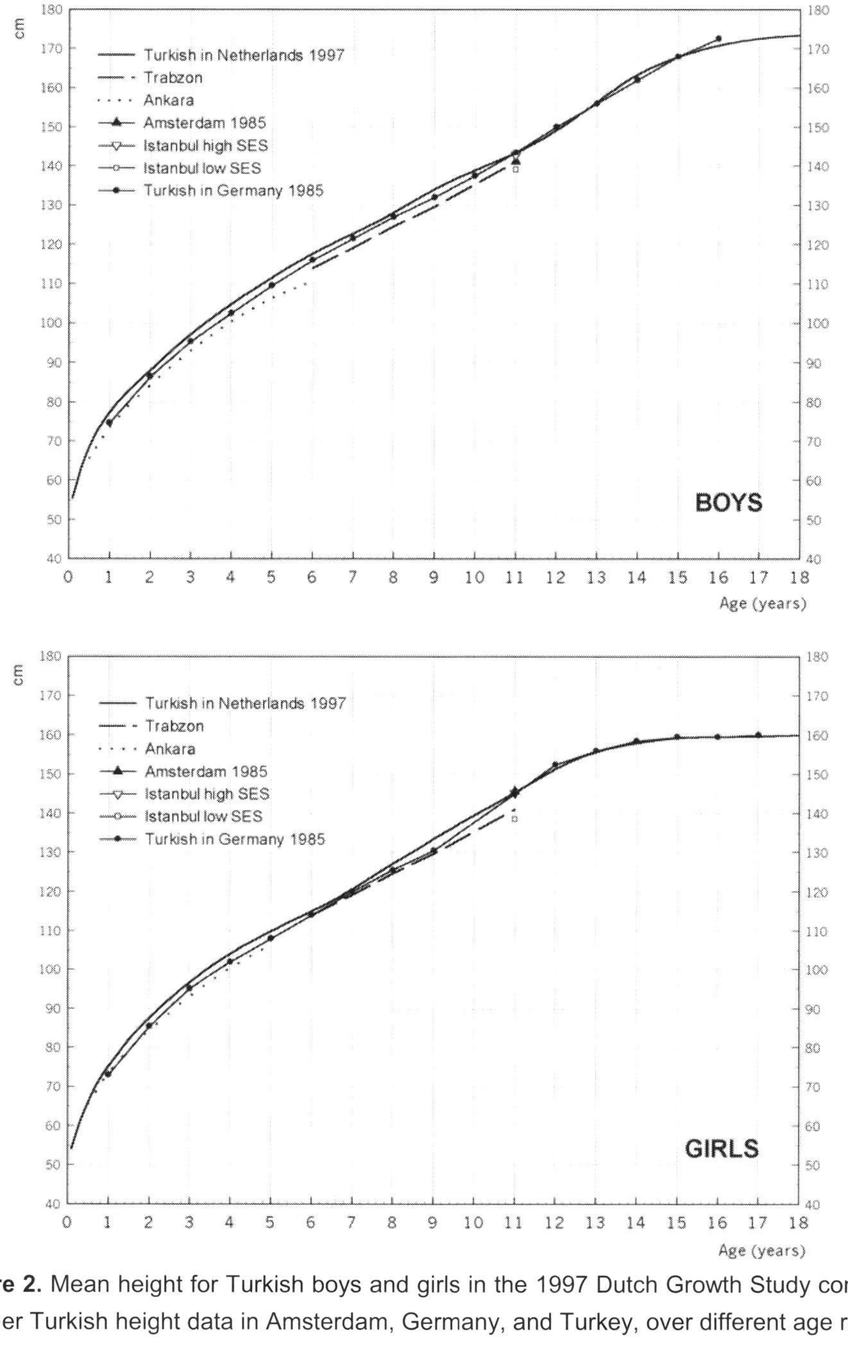

Figure 2. Mean height for Turkish boys and girls in the 1997 Dutch Growth Study compared to other Turkish height data in Amsterdam, Germany, and Turkey, over different age ranges.

Weight and BMI for age from 1 to 20 years

In table 4 weight for height reference data are shown. For a given height, the Turkish population is consistently heavier than the Dutch. Body mass index data compared to Dutch and Moroccan data and to international standards for overweight and obesity, will be reported elsewhere (Fredriks *et al*, submitted).

Table 4. Weight for height references for Turkish children, aged 0-20 years, in two age groups, <16 years, and ≥16.0 years. ~ insufficient number of data.

Height (cm)	**Boys Weight (kg)**			**Girls Weight (kg)**		
Age<16.0 y	**-2SD**	**0SD**	**+2SD**	**-2SD**	**0SD**	**+2SD**
50	2.9	3.5	4.1	3.0	3.5	4.2
55	3.9	4.6	5.4	3.9	4.6	5.5
60	5.0	5.9	7.0	4.9	5.9	6.9
65	6.2	7.3	8.7	6.0	7.1	8.6
70	7.4	8.7	10.4	7.1	8.5	10.2
75	8.5	10.0	12.1	8.1	9.8	11.8
80	9.6	11.3	13.7	9.1	11.0	13.4
85	10.6	12.5	15.2	10.1	12.2	15.0
90	11.6	13.7	16.8	11.1	13.5	16.8
95	12.7	14.9	18.5	12.3	14.9	18.7
100	13.8	16.3	20.5	13.4	16.4	20.7
105	15.1	17.9	22.6	14.6	18.0	22.9
110	16.5	19.6	25.1	15.9	19.6	25.3
115	18.1	21.6	28.0	17.3	21.5	28.0
120	19.8	23.8	31.3	18.9	23.8	31.2
125	21.7	26.2	35.1	20.8	26.3	35.1
130	23.8	29.0	39.3	23.0	29.2	39.6
135	26.1	32.0	43.9	25.5	32.6	44.9
140	28.5	35.2	49.2	28.2	36.4	51.0
145	31.2	38.8	55.0	31.2	40.6	57.8
150	34.0	42.6	61.3	34.4	45.0	65.2
155	37.0	46.6	68.3	37.7	49.6	73.2
160	40.1	50.8	76.0	41.0	54.3	81.6
165	43.3	55.1	84.3	~	~	~
170	46.5	59.5	93.4	~	~	~
175	49.8	63.9	103.4	~	~	~
180	53.0	68.4	114.6	~	~	~
Age ≥16.0 y						
150	38.6	50.9	67.0	36.5	51.2	71.8
170	49.2	64.8	85.4	47.4	66.4	93.1
180	55.5	73.1	96.4	~	~	106.1

Sexual maturation

Table 5 contains the P_{50} (median age) values for pubic hair (PH), breast (B) and genital (G) development. The median age at onset of breast development (B2) in Turkish girls was 11.3 years, 0.6 years later than in Dutch girls (t=-2.53, p=0.006). However, the median age at menarche (M) was 12.8 years, 4.8 months earlier than Dutch girls (t=3.05, p=0.001). Also the other pubertal stages in Turkish girls occurred earlier than in Dutch girls. Thus, Turkish girls started puberty later but the progression through different stages seemed faster, on a population level. Longitudinal data are necessary for information about the rate at which an individual child passes through the consecutive stages. For Turkish boys a similar pattern was observed. Stage G2 occurred 0.7 years later, but they achieved stage G5 at a younger age (about one year faster).

Table 5. P_{50} ages (years) of reaching the stages of secondary sex characteristics for Turkish and Dutch boys and girls in the 1997 Dutch Growth Study.

Boys		**Turkish P_{50}**	**Dutch P_{50}**	**Girls**		**Turkish P_{50}**	**Dutch P_{50}**
Pubic hair	PH 2	12.0	11.7	Pubic hair	PH 2	11.1	11.0
	PH 3	13.3	12.9		PH 3	11.8	11.9
	PH 4	14.0	13.8		PH 4	12.2	12.7
	PH 5	14.5	15.0		PH 5	12.4	13.8
Genitalia	G 2	12.2	11.5	Breast	B 2	11.3	10.7
	G 3	13.3	12.9		B 3	11.8	11.9
	G 4	14.1	13.9		B 4	12.2	12.8
	G 5	14.5	15.3		B 5	12.4	14.3
				Menarche*		12.8	13.2

* The Turkish P_{10} and P_{90} ages for menarche were 11.0 and 14.6 years, for Dutch girls 11.8 and 14.9 years, respectively.

Association with demographic variables

Table 6 shows the standardised regression coefficients calculated by univariate analyses for demographic variables with height and BMI in three age groups for both Turkish and Dutch boys and girls. Height SDS was predicted by birthweight (+), target height (+), family size (-), and duration of maternal residence in the Netherlands (+). Birthweight was associated with both height and BMI SDS. Children attending special education and with lower educated parents showed lower height SDS. Similar findings were found in the oldest Dutch age group.

Table 6. Association for height SDS and BMI SDS. The significant demographic variables for the Turkish and the Dutch group were shown in 3 age groups (0-<5 years, 5-<12.5 years, and ≥12.5 years). For age group 5-<12.5 years; educational level of child is defined as 1=primary education, 0=special education. For age group ≥12.5 years; educational level of child is defined as 1=middle or higher secondary education, 0=primary or lower secondary education, similar for the educational level of parents. Other variables 1=yes, 0=no. Gender; 1=boy, 2=girl. ~ = no data available, *ß* =standardised *ß*.

	Univariate regression analysis					
Age group	**0-<5 y**		**5-<12.5 y**		**≥12.5 y**	
Height SDS	***ß* Turkish**	***ß* Dutch**	***ß* Turkish**	***ß* Dutch**	***ß* Turkish**	***ß* Dutch**
Maternal residence (y)		~	0.08*	~	0.10**	~
Educational level child	~	~	0.12**			0.09**
Educational level parents			0.07*	0.10*		0.11**
Familysize			-0.08*		-0.12***	
Birthrank					-0.07*	
Birthweight (kg)	0.37***	0.80***	~	0.40***	~	0.40***
Target height SDS	0.23**	0.52***	0.32***	0.66***	0.37***	0.72***
Two parent home		0.34**				
Smoking during pregnancy		-0.21***	~	~	~	~
≥ 2 wks breastfed		0.06*	~	~	~	~
BMI SDS						
Educational level child	~	~		-0.33*		-0.07*
Educational level parents				-0.15***		-0.16***
Familysize			-0.06*			-0.05**
Birthrank					-0.08*	0.04*
Birthweight (kg)	0.23***	0.40***	~	0.20***	~	0.10***
Target height SDS						-0.08***
Two parent home	-0.14***					
Mother working outside						0.08**
Smoking during pregnancy		-0.09*	~	~	~	~
Alcohol during pregnancy		0.08*	~	~	~	~

* P≥0.01- P<0.05, ** P≥0.001-P<0.01, *** P<0.001

The multivariate analysis resulted in the formulas shown in table 7 for both the Turkish and Dutch data, 17.2% of the variance in height SDS was explained by TH SDS and birthweight, for the Turkish 0-<5 years group. For the Dutch group more variables were relevant and the explained variance was higher (27.9%). In the older age groups the predictive effect of TH SDS on height SDS increased, a similar and even stronger effect was seen in the Dutch population. Duration of maternal residence in the Netherlands was associated with height SDS in the age groups >5 years. For the Turkish children, BMI SDS was predicted by birthweight (+) and a longer duration of maternal residence in the Netherlands (+) in the 0-<5 years group, but the explained variance was only 7.1%. For the Dutch, smoking in pregnancy (+), breastfeeding (+), and working status of the mother (+) were associated; however, the variance for prediction of BMI SDS was also small (r^2=6.6).

Table 7. Regression formulas for height SDS and BMI SDS based on multiple regression analysis for children of Turkish and Dutch origin in 3 age groups; I: 0-< 5 years; II: 5-< 12.5 years; and III: ≥12.5 years. Non significant variables in the multivariate regression model were removed, the significant variables are put in the final model. For BMI SDS no significant variables were found for the Turkish age group II and III.

	Age group	Formula	r^2 % variance
Turkish			
Height SDS	I	-2.0 + 0.22 TH-SDS*** + 0.65 birthweight***	17.2
	II	0.48 + 0.44 TH-SDS***– 0.41 two parent family + 0.14 duration of stay mother** – 0.04 age (yr)	17.7
	III	-0.47 + 0.46 TH-SDS*** + 0.17 duration of maternal residence	15.9
BMI SDS	I	-1.67 + 0.14 duration of stay mother*** + 0.4 birthweight***	7.1
Dutch			
Height SDS	I	-2.76 + 0.7 birthweight*** + 0.42 TH SDS*** + 0.08 region** - 0.14 alcohol use + 0.03 age** (yr) + 0.1 gender*	27.9
	II	-0.62 + 0.2 birthweight*** + 0.62 TH SDS*** + 0.1 region -0.1 parental education	28.5
	III	-1.13 + 0.2 birthweight*** + 0.66 TH SDS*** + 0.11 region** + 0.11 gender*	29.1
BMI SDS	I	-1.65 + 0.5 birthweight*** - 0.06 TH SDS* + 0.11 working mother + 0.2 smoking*** + 0.09 breastfeeding**	6.6
	II	-0.55 + 0.3 birthweight*** + 0.1 region** - 0.19 parental education	3.6
	III	-0.61+ 0.2 birthweight*** - 0.1 TH SDS** + 0.03 region* + 0.13 working mother** - 0.05 family size*	2.4

* $p \geq 0.01$- $p < 0.05$, ** $p \geq 0.001$- $p < 0.01$, *** $p < 0.001$
'Duration of maternal residence in the Netherlands' was only asked the Turkish children, 'Region' 1=south, 2=mid, 3=north, was only asked the Dutch children.

Discussion

This study provides up-to-date growth references for length, height, weight, BMI, and head circumference for age, weight for height, and pubertal stages for Turkish children living in the Netherlands. We excluded third generation Turkish children (parents of Turkish origin but both born in the Netherlands) but national statistics showed that this generation is as yet very small (25). The constructed charts can be particularly used for growth monitoring of Turkish children who have heights below –2 SD on the regular Dutch growth charts. About 10% of the prepubertal Turkish children were below the Dutch –2 SD lines, of whom the majority should still be labelled as growing normally according to the Turkish growth chart.

With respect to body length and height, differences compared to the Dutch population were small during infancy, but increased to approximately -1.5 SD (or 10 cm) at 20 years of age. The height reference lines were practically horizontal at 19 years for boys and 17 years for girls, at an earlier age than Dutch males and females (at 21 and 19 years, respectively). Similar results have been described in Sweden (12). Mean heights were similar to those of Turkish children in Germany (11) and to children living in higher socio-economic class in urban Turkey in the 1970s (6), as well as more recently (male final height 174.2 cm) (24). Within Turkey, however, large height differences have been observed between high and low SES groups and between urban and rural regions (23). The majority of Turkish children in the Netherlands came from rural areas, which suggests that they are taller than their age-peers living in rural Turkey.

The mean secular trend appears close to 2 cm/20 years, which is similar to findings from a recent study in Turkish children aged 5-11 years in a high SES group in Ankara (5). It is difficult to predict whether the secular change will further increase, as has been found in most ethnic groups (1), with more integration into Dutch culture, the health system and nutritional status. The secular change might be smaller than expected because family forming has continued to occur with partners from Turkey (26).

The height differences between the Dutch and Turkish population in the Netherlands are probably mainly due to genetic differences, but also environmental determinants could be involved. There is a difference in health indicators, illustrated by a 2-3 times higher mortality of Turkish and Moroccan children than of Dutch children associated with accidents and infections during summer visit to Turkey and congenital disorders (27,28). Turkish children did not consult a GP more often, but the morbidity presented differed (29).

With respect to nutrition, Turkish children more often skipped their breakfast (30) (11%, compared with 2.5 % in Dutch children). They had a relatively lower intake of micronutrients, dairy products and saturated fats and a higher intake of soft drinks and sugar (30). Also more iron deficient anaemia and vitamin D deficiency have been described (30,31). Also after a longer stay in the Netherlands, 80% still consume traditional food, possibly because most mothers belonged to first generation immigrants. The educational level, another determinant for growth (32), is relatively low and similar to observations of Turkish families in Sweden (12). However, in the 0-<5 years group in our study, the demographic profile showed significantly higher parental educational levels and more paternal employment than in the two older age groups.

Compared to available Turkish data on pubertal development, stage G2 was 0.6 years later than in high SES boys in Elaziğ (11.6 years) and in good agreement with English, North American and South African data (10). In older urban studies, G2 ran from 11.0 to 12.0, the higher the SES the earlier G2 (8,33,34). In girls, menarche occurred almost 5 months earlier compared to Dutch girls, at 12.8 years. Part of the difference in age at menarche may be associated with the higher BMI values for age

(35,36). These data are in good agreement with Turkish girls in Istanbul, (12.8 years, 12.4 high SES, 13.2 low SES) (8) and Turkish girls in Bremen (12.9 years) (37).

Only a few demographic variables were associated with measures of height and BMI and we did not find any significant effect of educational level. Even by combining the three age groups to obtain more power, we did not find any significant effect for educational level of the parents nor the child. A positive effect of a higher educational level of child and parents, as found in the Dutch children (2) was only found in the 5-≤12.5 years group in univariate analysis but this effect disappeared in the multivariate analysis. This might be caused by the fact that 80% of the parents had none, primary or low secondary level education, resulting in a homogeneous SES group also found in the educational level of the child. The only significant effect was found for children attending special education. They had lower heights than children in regular schools, similarly to Dutch children (2). Parental height was the most important predicting factor for height especially in the older age groups for both the Turkish and Dutch data. The positive effect of duration of maternal residence in the Netherlands for height was strongest in children after puberty. In this age group, 26% of the mothers had resided for more than 20 years in the Netherlands and possibly the effect can be detected better over this long period, with a longer benefit of the environmental circumstances, than in the 0-<5 years group where we found no effect.

In conclusion, separate growth charts for Turkish children in the Netherlands are useful for clinical purposes. Turkish children have lower mean heights and higher weight for height and BMI values. They start puberty later compared to Dutch children, but pubertal progression seemed faster; however, for interpretation one should be aware that our data are derived from a cross-sectional study. Median age at menarche (12.8 years) is 5 months earlier compared to girls of Dutch origin.

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Chapter 8

Height, weight, body mass index, and pubertal development references for children of Moroccan origin in the Netherlands.

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Abstract

Objectives To provide growth and sexual maturation reference data for Moroccan children living in the Netherlands and to compare them with the reference data of children of Dutch origin.
Methods Cross-sectional growth and demographic data were collected from 2,880 children of Moroccan origin and 14,500 children of Dutch origin living in the Netherlands in the age range 0-20 years. Growth references for length, height, weight, weight for height, body mass index (BMI), and head circumference were constructed with the LMS method. Predictive variables for height and BMI were assessed by univariate and multivariate regression analyses. Reference curves for sexual maturation and menarche were estimated by a generalized additive model.
Results Moroccan young adults were on average 9 cm shorter than their Dutch contemporaries. Mean final height was 174.7 cm for males and 161.3 cm for females. Height differences in comparison with Dutch children started from 2 years onwards. Height SDS was predominantly associated with target height. Compared to Dutch children, maturation stages started 0.2-0.9 years later for girls and boys, respectively, but the progression through puberty seemed faster. In girls median age at menarche was 12.9 years, 3.6 months earlier than Dutch girls. BMI of Moroccan children was slightly above that of Dutch children, especially for girls. BMI SDS was associated with birthweight in the age group 0-<5 years.
Conclusions Moroccan children are considerably shorter and girls are more overweight than Dutch children. Separate growth charts for Moroccan children in the Netherlands are therefore useful for growth monitoring.

Height, weight, body mass index, and pubertal development references for children of Moroccan origin in the Netherlands.

Introduction

For optimal growth monitoring recent reference data from a representative sample of the population are necessary. However, it is still unresolved how one could best deal with the sharp increase in the genetic variation in the population's height caused by immigration. Nowadays, more than two third of the children visiting Well Baby Clinics and youth health care in the Dutch large cities are of foreign decent, a quarter of them from Moroccan or North African origin (1). One option is to prepare reference data for the actual ethnic mix, but this would decrease its efficacy for detecting growth disorders. Most immigrant children, of whom the Moroccan and Turkish children form the majority, are substantially shorter than the relatively tall Dutch children. This would imply that a substantial part of immigrant children would be considered abnormally short for age on a predominantly Dutch growth chart, but normal compared to their own specific growth chart.

The other option is to prepare references for the ethnic Dutch population, and additional references for the largest immigrant populations. Besides being a better tool for growth monitoring, this would also provide the possibility to study the secular growth trend and (indirectly) the health status of these ethnic groups. In the designing phase of the Fourth Dutch Growth Study, we decided to take the second option. Data were collected from originally Dutch children (2), as well as from the two largest migrant groups, the Moroccan and the Turkish population.

In an earlier paper (3) we described growth of Turkish children. In the present paper we report growth references for height, weight, weight for height, body mass index, head circumference for age, and sexual maturation for children of Moroccan origin in the age range 0-20 years, living in the Netherlands in 1997. We compared them with the 1997 Dutch data and with the few available Moroccan growth data (4-6). Finally we studied the association between height and body mass index (BMI) and demographic variables.

Methods

Subjects

In a cross-sectional design, length, height, weight, head circumference, and sexual maturation were measured of 2,882 children of Moroccan origin living in the largest four cities in the Netherlands; Amsterdam, Rotterdam, Utrecht and The Hague. Moroccan children were included if both biological parents were born in Morocco (n=2,868), or if one parent was born in Morocco and the other in another North African country (n=14). Children with diagnosed growth disorders and those on medication known to interfere with growth were excluded from the sample (n=26). In the same

1997 Dutch Growth Study, growth data of 14,500 children of Dutch origin were similarly collected over the country, including in the large cities (n=1,505). Detailed method of measuring is described elsewhere (2).

Methods

Pubertal stages were determined by visual inspection, using the criteria and definitions described by Tanner (7), extended by a sixth stage for pubic hair. The age at menarche was determined by the 'status quo method', i.e. each girl was asked whether or not she had had her first period. A questionnaire, filled in by a health professional, was used to assess demographic variables. Duration of maternal residence in the Netherlands was divided in <6.0, 6.0-<11.0, 11.0-<20.0, and ≥20.0 years. The educational level of the child was determined at the time of measurement. If an adolescent of >15 years of age had left any educational system, the highest completed education was recorded. As an indicator of socio-economic status the highest completed educational level of the parents was used. Family size was defined by the number of children in a household (1-2, 3-4, ≥5).

Other variables were target height, the percentage working (part-time/full-time) parents in families, and one or two parent families. Only in the 0-<5 years group data were collected on birthweight, and whether the mother smoked or consumed alcoholics during pregnancy or (had) breastfed her child. Birthweight and parental height were obtained by questioning the parents themselves. For the children of 5 years and older, this was asked for in the personal invitation letter. Associations between demographic variables and height SDS and BMI SDS are described for both the Moroccan and the Dutch group.

Statistical analysis

Reference standard deviation (SD) curves were estimated by the LMS method (2,8). Reference curves for menarche and the stages of secondary sex characteristics were estimated by generalized additive models (9). Except for menarche, only P_{50} values could be calculated, as the more extreme P values were not sufficiently reliable because of insufficient numbers of children.

The difference in distribution of the demographic variables over the three age groups (0-<5.0, 5.0-<12.5, and ≥12.5 years) was calculated by a chi square test. The associations between demographic variables and height SDS and BMI SDS were assessed by univariate and multivariate regression analyses in three age groups. Both age and gender were included into the regression analyses.

An adapted target height (TH) formula was used, the same as we used for calculating the TH for Turkish children in the Netherlands: (paternal height + maternal height ±

13)/2 +2 cm (3). TH SDS was calculated as follows: (TH- mean Moroccan height at 20 years of age) /SD at 20 years of age.

Results

Table 1 shows descriptive information of the Moroccan and the Dutch sample for demographic variables, birthweight, and parental heights per age group. Based on the Moroccan children's age and the duration of the maternal residence in the Netherlands, we calculated that 13.7% belonged to the first and 56.7% to the second generation. In 29.6% of the children this could not be determined, but according to national statistics they were expected to be merely second generation.

The distribution of the demographic variables was largely different from the Dutch sample, especially for educational level, working status of the parents, and familysize. However, in the youngest group these differences decreased. No Moroccan mothers used alcohol or smoked during pregnancy and more Moroccan infants than Dutch infants were breastfed. The characteristics of the sample were close to minority statistics (10,11).

Length, weight, and head circumference of infants

Table 2 contains the reference data (mean and standard deviation scores (SDS)) for length, weight, and head circumference for Moroccans aged 0-60 weeks. Hardly any length differences were observed compared to Dutch references. Until 22 weeks of age, Moroccan infants were slightly shorter (on average -0.5 cm), thereafter slightly longer, with a mean difference of +0.2 cm. Also weight comparisons showed minimal weight differences compared with Dutch infants; the mean difference was +0.2 kg, and girls showed the first 3 months no differences at all. Head circumference was in Moroccan infants on average 0.6 cm larger.

Table 1. Percentage and total number of children from Moroccan and Dutch origin for demographic variables per age group (0-<5 years, 5-<12.5 years, and ≥12.5 years). Significant differences between the three Moroccan age groups are marked.

M=mother, F=father, * *p* <0.05 ** *p*< 0.0001, ~ no data available.

	0-<5 y		**5-<12.5 y**		**≥12.5 y**	
	Moroccan	**Dutch**	**Moroccan**	**Dutch**	**Moroccan**	**Dutch**
Duration of stay M	(*n*=832)		(*n*=937)		(*n*=915)	
<6 yr	24.8	~	7.0	~	9.3	~
6-10 yr	25.2	~	20.4	~	18.9	~
11-20 yr	37.7	~	60.3	~	51.9	~
≥20 yr	12.3	~	12.3	~	19.9	~
Educ level child**	(*n*=916)	(*n*=5739)	(*n*=954)	(*n*=3340)	(*n*=905)	(*n*=5335)
Prim educ	~	~	97.1	94.8	11.2	2.7
Lower sec educ	~	~	1.5	1.3	68.3	45.0
Middle sec educ	~	~	0.5	1.8	15.2	40.3
Higher sec educ	~	~	~	~	0.3	10.1
Spec educ	~	~	0.9	2.1	5.0	1.9
Educ level parents**	(*n*=493)	(*n*=5613)	(*n*=925)	(*n*=3174)	(*n*=854)	(*n*=4001)
None/primary	61.1	0.3	91.5	2.3	93.6	2.5
Lower sec educ	26.8	18.8	5.7	33.0	4.2	36.9
Middle sec educ	7.9	40.9	1.8	32.2	1.9	29.3
Higher sec educ	4.3	39.9	1.0	32.5	0.4	31.3
Familysize**	(*n*=559)	(*n*=5732)	(*n*=975)	(*n*=3362)	(*n*=961)	(*n*=5401)
1-2	44.0	81.4	7.8	60.2	6.2	67.2
3-4	32.0	17.2	35.8	37.3	24.4	29.8
≥5	24.0	1.3	56.4	2.2	69.3	3.0
Working M outside*	9.4	58.5	6.6	53.6	5.8	58.9
	(*n*=543)	(*n*=567)	(*n*=965)	(*n*=3183)	(*n*=931)	(*n*=4910)
Working F outside**	53.1	97.4	40.8	94.4	33.3	92.7
	(*n*=452)	(*n*=5590)	(*n*=920)	(*n*=2454)	(*n*=880)	(*n*=3702)
Two parent family*	97.1	97.6	94.9	93.6	94.0	87.4
	(*n*=559)	(*n*=5735)	(*n* =964)	(*n*=3353)	(*n*=933)	(*n*=5388)
Mean height M**	160.9	169.2	162.5	168.3	163.0	168.1
	(*n*=399)	(*n*=5596)	(*n*=649)	(*n*=3288)	(*n*=546)	(*n*=4788)
Mean height F	171.3	182.3	171.5	181.1	171.7	180.5
	(*n*=318)	(*n*=5511)	(*n*=660)	(*n*=3221)	(*n*=553)	(*n*=4744)
Smoked in pregnancy	0.6	23.1	~	~	~	~
	(*n* =538)	(*n* =5499)				
Alcohol in pregnancy	0.0	16.7	~	~	~	~
	(*n*=540)	(*n*=5491)				
≥2 weeks breastfed	83.5	69.0	~	~	~	~
	(*n*=537)	(*n*=5480)				

Table 2. Reference data (0 SD, SD, and ±2 SD, when appropriate) for length, weight, and head circumference for boys and girls of Moroccan origin living in the Netherlands in the age-range 3.0-60.0 weeks in the 1997 Dutch Growth Study.

Boys							
Age	**Length**			**Weight**		**Head**	
wk	**Mean**	**SD**	**-2SD**	**0SD**	**+2SD**	**Mean**	**SD**
3.0	53.2	2.0	3.4	4.4	5.3	38.6	1.3
4.0	54.0	2.0	3.5	4.5	5.5	38.9	1.3
6.0	55.5	2.0	3.8	4.9	6.0	39.7	1.3
8.0	57.0	2.0	4.1	5.3	6.4	40.4	1.3
10.0	58.5	2.1	4.4	5.6	6.8	41.0	1.3
12.0	59.9	2.1	4.6	6.0	7.3	41.6	1.4
14.0	61.2	2.1	4.9	6.3	7.7	42.2	1.4
16.0	62.4	2.1	5.2	6.6	8.1	42.7	1.4
18.0	63.6	2.2	5.4	7.0	8.5	43.1	1.4
20.0	64.7	2.2	5.6	7.3	8.9	43.5	1.3
22.0	65.8	2.2	5.9	7.5	9.2	43.9	1.3
24.0	66.8	2.2	6.1	7.8	9.6	44.2	1.3
26.0	67.9	2.2	6.3	8.1	9.9	44.5	1.3
28.0	68.8	2.3	6.5	8.3	10.2	44.9	1.3
32.0	70.6	2.3	6.9	8.8	10.8	45.4	1.3
36.0	72.2	2.4	7.2	9.2	11.3	46.0	1.3
40.0	73.6	2.4	7.5	9.6	11.8	46.4	1.3
44.0	74.9	2.5	7.8	10.0	12.3	46.8	1.3
48.0	76.1	2.6	8.1	10.3	12.7	47.1	1.3
52.0	77.1	2.6	8.3	10.6	13.1	47.5	1.3
56.0	78.1	2.7	8.5	10.8	13.4	47.7	1.3
60.0	79.0	2.8	8.7	11.1	13.8	48.0	1.3

Girls							
Age	**Length**			**Weight**		**Head**	
wk	**Mean**	**SD**	**-2SD**	**0SD**	**+2SD**	**Mean**	**SD**
3.0	52.1	2.4	2.9	3.9	4.9	37.4	1.2
4.0	52.9	2.4	3.0	4.1	5.1	37.7	1.3
6.0	54.4	2.4	3.3	4.4	5.6	38.4	1.3
8.0	55.9	2.5	3.6	4.8	6.0	39.0	1.3
10.0	57.3	2.5	3.8	5.1	6.4	39.5	1.3
12.0	58.7	2.5	4.1	5.4	6.8	40.1	1.3
14.0	60.0	2.5	4.3	5.8	7.3	40.6	1.4
16.0	61.2	2.6	4.6	6.1	7.7	41.1	1.4
18.0	62.4	2.6	4.8	6.4	8.1	41.6	1.4
20.0	63.5	2.6	5.0	6.7	8.4	42.1	1.4
22.0	64.6	2.6	5.3	6.9	8.8	42.5	1.4
24.0	65.6	2.6	5.5	7.2	9.2	43.0	1.5
26.0	66.5	2.6	5.7	7.5	9.5	43.4	1.5
28.0	67.4	2.6	5.9	7.7	9.8	43.7	1.5
32.0	69.0	2.6	6.3	8.2	10.5	44.4	1.5
36.0	70.5	2.6	6.6	8.6	11.0	44.9	1.5
40.0	71.7	2.6	6.9	9.0	11.6	45.3	1.6
44.0	72.9	2.6	7.2	9.4	12.1	45.6	1.6
48.0	73.9	2.6	7.5	9.7	12.5	46.0	1.6
52.0	74.9	2.6	7.8	10.1	13.0	46.2	1.6
56.0	75.9	2.6	8.0	10.4	13.4	46.5	1.6
60.0	76.8	2.6	8.2	10.6	13.8	46.7	1.6

Height, weight, and BMI for age for 1 to 20 years

In figure 1 Moroccan growth charts are shown, compared with Dutch references. The Moroccan SD lines are located approximately -1.5 SD below the Dutch SD lines (12, see also Appendix 2). Height values are shown in table 3, together with weight and body mass index references for the age group 1-20 years. At one year of age, Moroccan boys were slightly taller (+0.6 cm) than Dutch boys. However, from 2 years onwards, both boys and girls were increasingly shorter, up to more than 9 cm at 20 years of age. Mean final height at 20 years of age was for boys 174.7 cm (Dutch 184.0), for girls 161.3 cm (Dutch 170.6). At 7 years, about half of the final height difference was achieved, and during puberty this difference increased with another 4 cm, similar as in children of Turkish origin. Reference lines seemed to level around 17.5 and 15.5 years for Moroccan boys and girls, respectively, and they reached final height at a younger age compared to Dutch adolescents. If Moroccan children would be compared to Dutch growth charts, 9.8% of the boys and 11.3% of the girls would have a height below –2 SD (and on average 5% below –2.5 SD).

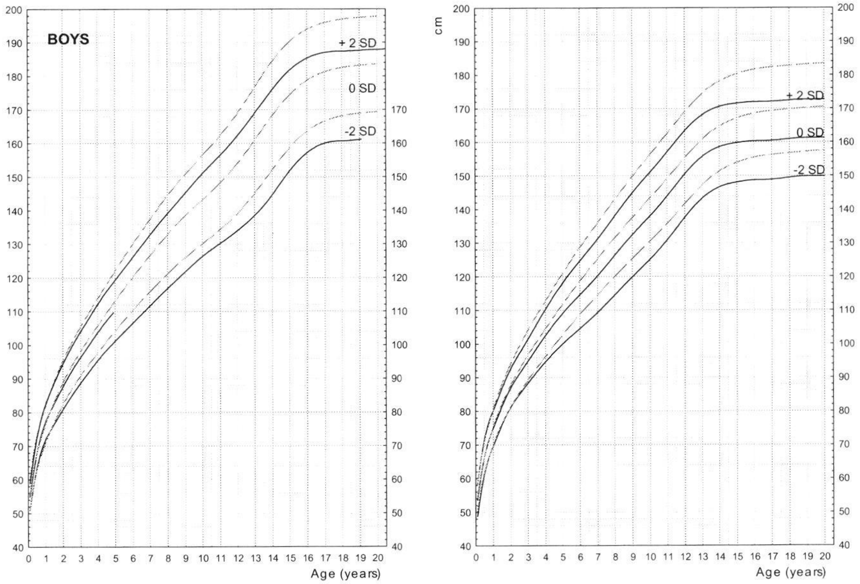

Figure 1. 0 SD (mean) and ±2 SD height reference lines for Moroccan (solid) and Dutch (dotted) boys and girls in the age range 1-20 years, based on the 1997 Dutch Growth Study.

Table 3. Reference data (0 SD, SD and ±2 SD, when appropriate) for length (1 year of age, cm), height (cm), weight (kg), and BMI (kg/m^2) for boys and girls of Moroccan origin in the Netherlands in the age-range 1-20 years in the 1997 Dutch Growth Study.

			Boys					
Age	**Height**			**Weight**			**BMI**	
Years	**Mean**	**SD**	**-2SD**	**0SD**	**+2SD**	**-2SD**	**0SD**	**+2SD**
1.0	77.2	2.6	8.3	10.6	13.1	14.7	17.8	21.1
2.0	87.7	3.4	10.3	13.2	16.7	14.1	17.0	20.6
3.0	96.3	3.8	11.9	15.2	19.5	13.6	16.4	20.2
4.0	103.8	4.2	13.3	17.1	22.4	13.3	16.1	20.1
5.0	110.3	4.5	14.8	19.2	25.6	13.1	15.9	20.3
6.0	116.2	4.9	16.5	21.4	29.3	13.1	15.9	20.7
7.0	122.2	5.3	18.2	23.9	33.6	13.2	16.0	21.2
8.0	128.0	5.6	19.9	26.4	38.4	13.3	16.2	21.9
9.0	133.4	5.9	21.8	29.2	43.8	13.5	16.5	22.6
10.0	138.7	6.2	23.7	32.2	49.6	13.7	16.8	23.4
11.0	143.3	6.6	25.8	35.5	55.7	14.0	17.2	24.4
12.0	148.1	7.1	28.2	39.2	62.2	14.4	17.7	25.3
13.0	153.8	7.6	31.0	43.5	69.2	14.9	18.3	26.3
14.0	160.3	7.8	34.6	48.7	76.5	15.3	18.9	27.4
15.0	166.8	7.5	38.8	54.2	83.1	15.8	19.5	28.4
16.0	171.2	7.0	42.5	58.7	87.6	16.2	20.0	29.3
17.0	173.5	6.7	45.6	62.1	90.5	16.7	20.6	30.2
18.0	174.0	6.7	48.1	64.5	92.1	17.1	21.1	31.1
19.0	174.3	6.6	50.2	66.5	93.1	17.5	21.6	31.9
20.0	174.7	6.6	52.2	68.2	93.9	17.9	22.1	32.8

			Girls					
Age	**Height**			**Weight**			**BMI**	
Years	**Mean**	**SD**	**-2SD**	**0SD**	**+2SD**	**-2SD**	**0SD**	**+2SD**
1.0	74.9	2.6	7.8	10.1	13.0	14.9	17.7	21.6
2.0	86.8	2.9	10.0	12.9	17.2	14.3	17.0	21.1
3.0	94.8	3.3	11.5	14.8	20.2	13.7	16.4	20.8
4.0	102.4	3.9	13.0	16.8	23.5	13.4	16.1	21.0
5.0	109.0	4.5	14.5	18.9	27.4	13.2	16.1	21.4
6.0	114.6	5.0	16.0	21.1	31.6	13.1	16.1	22.0
7.0	120.2	5.5	17.6	23.4	36.2	13.1	16.2	22.6
8.0	126.4	5.9	19.2	26.0	41.3	13.1	16.4	23.2
9.0	132.4	6.3	21.0	28.8	46.9	13.2	16.7	24.0
10.0	138.0	6.5	23.1	32.2	52.8	13.5	17.2	24.9
11.0	144.0	6.6	25.7	36.5	59.3	13.9	17.8	25.9
12.0	150.5	6.4	29.1	41.9	66.2	14.3	18.6	27.1
13.0	155.6	6.2	33.1	47.4	72.5	14.9	19.4	28.3
14.0	158.6	6.0	36.7	51.7	76.9	15.4	20.2	29.4
15.0	159.8	5.9	39.4	54.6	79.4	15.9	20.9	30.3
16.0	160.3	5.8	41.1	56.4	80.9	16.3	21.6	31.2
17.0	160.4	5.8	42.2	57.6	81.9	16.6	22.2	31.9
18.0	160.9	5.7	43.0	58.5	82.7	16.9	22.7	32.6
19.0	161.2	5.7	43.6	59.1	83.2	17.2	23.2	33.3
20.0	161.3	5.7	44.1	59.7	83.8	17.5	23.7	33.9

In table 4 weight for height reference data are shown. Moroccan SD lines are located slightly above the Dutch lines over the whole age range, in girls more than in boys.

Thus, the prevalence of overweight and obesity is higher than in children of Dutch origin.

Table 4. Weight for height reference data (0 SD and ±2 SD) for Moroccan children, aged 0-20 years, in two age groups; <16.0 years and ≥16.0 years.

~ insufficient number of data.

Height (cm)	Boys Weight (kg)			Girls Weight (kg)		
Age<16.0 y	**-2SD**	**0SD**	**+2SD**	**-2SD**	**0SD**	**+ 2SD**
50	2.9	3.6	4.1	2.9	3.5	4.3
55	3.9	4.8	5.5	3.8	4.6	5.6
60	5.0	6.07	7.1	4.8	5.8	7.1
65	6.1	7.4	8.6	5.9	7.1	8.7
70	7.2	8.7	10.2	7.1	8.5	10.5
75	8.3	10.0	11.8	8.3	9.9	12.2
80	9.3	11.2	13.4	9.3	11.1	13.9
85	10.2	12.4	14.9	10.3	12.3	15.5
90	11.2	13.6	16.5	11.3	13.5	17.3
95	12.2	14.8	18.1	12.3	14.8	19.1
100	13.3	16.2	19.9	13.4	16.1	21.2
105	14.5	17.6	21.9	14.6	17.6	23.5
110	15.8	19.2	24.2	15.9	19.3	26.1
115	17.3	21.0	26.7	17.4	21.1	29.0
120	18.9	23.0	29.6	18.9	23.2	32.3
125	20.7	25.2	32.9	20.7	25.5	36.0
130	22.7	27.7	36.6	22.6	28.1	40.3
135	25.0	30.5	40.9	24.8	31.2	45.1
140	27.4	33.6	45.7	27.3	34.6	50.5
145	30.1	36.9	51.0	30.0	38.4	56.4
150	32.9	40.4	56.8	32.9	42.5	62.8
155	35.9	44.1	63.1	35.9	46.9	69.5
160	39.1	48.0	69.9	38.8	51.3	76.4
165	42.3	52.0	77.3	~	~	~
170	45.6	56.0	85.2	~	~	~
175	49.0	60.1	93.7	~	~	~
180	52.3	64.2	103.1	~	~	~
Age ≥16.0 y						
160	35.8	47.2	62.4	38.9	53.0	72.2
170	46.7	61.6	81.4	46.2	62.9	85.8
180	53.3	70.4	92.9	~	~	93.5

Sexual maturation

The P_{50} values for pubic hair (PH), breast (B) and genital (G) development are shown in table 5. In Moroccan girls the P_{50} of onset of puberty for girls (B2) was 0.2 years later than in Dutch girls. The other stages occurred at younger ages, suggesting that Moroccan girls start puberty later but that the progression through different stages is faster. The median age at menarche (M) was 12.9 years, 0.3 years earlier than Dutch girls (2), but close to the menarcheal age of Turkish girls in the Netherlands (12.8 years) (3). In the two oldest age groups 3.1% of the girls used contraception pills (Dutch girls 16.7%). In Moroccan boys the onset of puberty (genital stage G2) was 0.9 years later, but they achieved stage G5 almost at the same age as Dutch boys.

Table 5. P_{50} ages (years) of reaching the stages of secondary sex characteristics for Moroccan and Dutch boys and girls in the 1997 Dutch Growth Study.

Boys		**Moroccan P_{50}**	**Dutch P_{50}**	**Girls**		**Moroccan P_{50}**	**Dutch P_{50}**
Pubic hair	PH 2	12.5	11.7	Pubic hair	PH 2	11.0	11.0
	PH 3	13.2	12.9		PH 3	11.8	11.9
	PH 4	13.9	13.8		PH 4	12.4	12.7
	PH 5	15.2	15.0		PH 5	12.5	13.8
Genitalia	G 2	12.4	11.5	Breast	B 2	10.9	10.7
	G 3	13.2	12.9		B 3	11.7	11.9
	G 4	13.6	13.9		B 4	12.4	12.8
	G 5	15.2	15.3		B 5	12.6	14.3
				Menarche*		12.9	13.2

* The Moroccan P_{10} and P_{90} ages for menarche were 11.5 and 14.4 years, for Dutch girls 11.8 and 14.9 years, respectively.

Table 6. Association for height SDS and BMI SDS. The significant demographic variables for Moroccan (M) and Dutch (D) children were shown in 3 age groups (0-<5 years, 5-<12.5 years, and ≥12.5 years). For age group 5-<12.5 years; educational level of child is defined as 1=primary education, 0=special education. For age group ≥12.5 years; educational level of child is defined as 1=middle or higher secondary education, 0=primary or lower secondary education, similar for the educational level of parents. Other variables 1=yes, 0=no. Gender; 1=boy, 2=girl. ~ = no data available, *ß* =standardised *ß*.

	Univariate regression analysis					
Age group	**0-<5 y**		**5-<12.5 y**		**≥12.5 y**	
Height SDS	***ß* M**	***ß* D**	***ß* M**	***ß* D**	***ß* M**	***ß* D**
Maternal residence (y)		~	0.08**	~		~
Educational level child	~	~			0.11**	0.09**
Educational level parents			0.07*	0.10*	0.09**	0.11**
Familysize			-0.07*		-0.11***	
Birthrank			-0.08*			
Birthweight (kg)	0.35***	0.80***	~	0.40***	~	0.40***
Target height SDS	0.26***	0.52***	0.29***	0.66***	0.26***	0.72***
Two parent home		0.34**				
Smoking during pregnancy		-0.21***	~	~	~	~
≥ 2 weeks breastfed		0.06*	~	~	~	~
BMI SDS						
Educational level child	~	~		-0.33*		-0.07*
Educational level parents				-0.15***		-0.16***
Familysize			-0.06*			-0.05**
Birthrank					-0.08*	0.04*
Birthweight (kg)	0.28***	0.40***	~	0.20***	~	0.10***
Target height SDS						-0.08***
Mother working outside						0.08**
Smoking in pregnancy	0.09*	-0.09*	~	~	~	~
Alcohol during pregnancy		0.08*	~	~	~	~

* *p*≥0.01-*p*<0.05, ***p*≥0.001-*p*<0.01, ****p*<0.001.

Demographic variables

Table 6 shows the results of univariate regression analyses for demographic variables with height SDS and BMI SDS in three age groups, for both Moroccan and Dutch boys and girls. Age and gender were included in the analyses; both had no significant effect. Only a few variables were related to height and BMI SDS. Height SDS was predominately predicted by target height. Educational level of the parents was in the two oldest age groups positively related to height. For BMI SDS were birthweight (+) and smoking of the mother during pregnancy (-) predictors. The demographic variables taken together in a multivariate regression analysis resulted in the regression formulas shown in table 7. For the 0-<5 years group, 19.0% of the variance in height SDS was explained by TH SDS and birthweight. 8.0% of the variance in BMI SDS was predicted by birthweight.

Table 7. Regression formulas for height SDS and BMI SDS based on multiple regression analysis for children of Moroccan and Dutch origin in 3 age-groups; I: 0-<5 years; II: 5-<12.5 years; and III: ≥12.5 years. Non significant variables in the multivariate regression model were removed, the significant variables are put in the final model. For BMI SDS no significant variables were found for age-group II and III.

	Age group	Formula	r^2 % variance
Moroccan			
Height SDS	I	-2.1 + 0.29 TH SDS*** + 0.6 birthweight (kg)***	18.4
	II	-0.11 + 0.34 TH SDS*** - 0.37 working status mother*	9.3
	III	0.84 + 0.28 TH SDS*** - 0.13 familysize* - 0.32 educational level child**	11.4
BMI SDS	I	-1.67 + 0.5 birthweight (kg)***	7.5
Dutch			
Height SDS	I	-2.76 + 0.7 birthweight*** + 0.42 TH SDS*** + 0.08 region** - 0.14 alcohol use + 0.03 age (y)** + 0.1 gender*	27.9
	II	-0.62 + 0.2 birthweight*** + 0.62 TH SDS*** + 0.1 region -0.1 parental education	28.5
	III	-1.13 + 0.2 birthweight*** + 0.66 TH SDS*** + 0.11 region** + 0.11 gender*	29.1
BMI SDS	I	-1.65 + 0.5 birthweight*** - 0.06 TH SDS* + 0.11 working mother + 0.2 smoking*** + 0.09 breastfeeding**	6.6
	II	-0.55 + 0.3 birthweight*** + 0.1 region** - 0.19 par. education	3.6
	III	-0.61 + 0.2 birthweight*** - 0.1 TH SDS** + 0.03 region* + 0.13 working mother** - 0.05 family size*	2.4

* p ≥0.01- p <0.05, ** p ≥0.001- p <0.01, *** p<0.001

'Duration of maternal residence in the Netherlands' was only asked the Moroccan children, 'Region' 1=south, 2=mid, 3=north, was only asked the Dutch children.

Discussion

This study provides growth charts for length, height, weight, BMI, head circumference, and pubertal development for boys and girls of Moroccan origin aged 0-20 years, living in the four large cities in the Netherlands. The sample consists of first and mainly second-generation immigrants and approximates national statistics (13). Until now, the third generation hardly exists because 85% of the second generation is younger than 20 years and most marriages have continued to occur with partners from Morocco (>80% of Moroccan women, 50% of Moroccan men) (14). The high percentage of Moroccan children who would be considered abnormally short for Dutch standards, illustrates that in these cases, separate growth charts for Moroccans in the Netherlands are useful to avoid unnecessary medical tests.

With respect to height, differences with Dutch heights started from 2 years onwards. Approximately 50% of the ultimate height difference already existed at 7 years of age and during puberty this further increased with another 4 cm. This was also found for the Turkish adolescents. Mean height difference increased from –0.2 SD to -1.3 SD (9.3 cm) for boys at 20 years of age, to -1.4 SD (9.6 cm) for girls. Apart from ethnic influence, Moroccans have relatively larger families and a lower level of education, income and working status, compared to the native Dutch population, and also compared to the Turkish population in the Netherlands (10).

Compared to the few available Moroccan growth data, heights of 17 year old Moroccans (173.5 cm) in the Netherlands (first and second generation) were similar to those of the first generation Moroccan immigrant boys in Israel in high socio-economic groups (mean height 173.8 cm; low SES: 170.8 cm). However 17 year old third generation Moroccan boys in Israel were slightly taller (mean height 172.9 cm; high SES: 174.3 cm) (5). With increasing integration in Dutch culture, increasing SES, and increasing intermarriage, a positive secular growth change for Moroccans can be expected. In future growth studies it is interesting to include third generation immigrants and include more detailed data on duration of stay in the Netherlands and to measure the parental heights. Positive secular changes have been encountered in many immigrant populations (15), such as in boys of Japanese parents in the United States who were after 20 years taller than their parents and had similar mean heights as their US peers.

Puberty started at a similar age as in Dutch adolescents, but the duration of puberty maturation stages seemed shorter. The median age at menarche for Moroccan girls in the Netherlands in 1997 was 12.9 years, 0.3 years earlier than Dutch girls. Similar data were found for Turkish adolescents (3). However, one should note that a cross-sectional design is not optimal for studying the longitudinal process of pubertal development.

In a Moroccan study in 1991, lower and middle class girls in Marrakesh had a median menarcheal age of 13.75 years, which was 0.55 younger than observations in 1982 (14.3 years). This decrease of median age at menarche may be explained by decreasing family sizes (9 to 7.7 children), better nutrition and standards of care, and a decrease in infections (4). Considering a secular trend of 0.55 years per decade, one would expect a median age of 13.4 years in 1997 in Marrakesh, still later than in the Netherlands. Possibly, a further improvement of socio-economic conditions and decreasing family sizes (3.3 children) (16) next to 96% coverage by child health care (11), as well as a relatively high prevalence of overweight, are responsible for the relatively low age at menarche in Moroccan girls living in the Netherlands, almost identical to the mean age at menarche of Dutch girls.

The explained variance as a percentage by socio-economic variables was low for height and BMI. This is probably partially explained by a homogeneous socio-economic group. In this study, the association between educational level and height was only found in the two oldest groups. Both educational levels of the child and parents were positively associated with height SDS and negatively with BMI SDS. Increasing family sizes were negatively associated with both height SDS and BMI SDS. In other studies, low parental social status, low paternal employment status, and large family sizes were reported to be associated with relatively lower heights and later onset of sexual maturation. However, it is usually difficult to separate the influence of socio-economic status from the effect of ethnicity (5). In the present study, the distribution of the demographic variables was largely different from the Dutch sample, especially for educational level, working status of the parents and familysize. However, in the age group <5 years differences decreased. This suggests that young parents may be better integrated in Dutch society.

Duration of maternal residence in the Netherlands was only positively associated with height in the 5-<12.5 years old, but this effect disappeared in the multiple variable analyses. The absence of the mother measured as working status of the mother was negatively associated with height. It was not associated with BMI, in contrast to our findings in the Dutch, where children in families with working mothers had higher BMI SDS.

Target height was the most prominent predictor for height, but its contribution to the explained variance was lower than observed in the Dutch population. This may be caused by the fact that the majority of parental heights were not measured, but asked from the parents joining the children. Older children all received a personal invitation letter for the study in which we asked for the height of the parents and the birthweight. Nevertheless, girls aged over 12.5 years probably overestimated the maternal heights because the mother's mean heights were found 1.9 cm taller than those of 20 years old girls in 1997. Maternal heights in the younger age groups were more appropriate and on average similar to 20 years old girls in 1997. This is expected because Moroccan girls had their first child on average at 23 years of age. For both the Moroccan and Turkish population we used the formula in which we assume a secular change of 2 cm in one generation (3).

In conclusion, separate growth charts for Moroccan children are useful for clinical purposes at this moment. Moroccan children have lower mean heights than their Dutch contemporaries. Moroccan girls have higher weight for height and BMI values, and start puberty later compared to Dutch girls. Median age at menarche (12.9 years) is 4 months earlier compared to Dutch girls.

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Chapter 9

Alarming prevalences of overweight and obesity for children of Turkish, Moroccan, and Dutch origin, according to the international standard.

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Introduction

Overweight and obesity pose a major public health challenge. Obesity in childhood often tracks into adulthood, with well-known adverse effects of obesity on health. Therefore, there is a need to identify children at high risk and to employ timely primary preventive actions. Previously, we found that overweight was more frequent for Dutch children with low socio-economic status that live in a large city (1). So far it is unknown whether children of ethnic minority groups living in the large cities are at increased risk. Here we report new data on the prevalence of overweight and obesity of children of Turkish, Moroccan, and Dutch origin in the Netherlands.

Participants, methods, and results

In the fourth Dutch Growth Study (1996-97) (1) data were collected of 14,500 children of Dutch origin, nation-wide and 2,904 children of Turkish (2) and 2,855 children of Moroccan (3) origin in four large cities (Amsterdam, Rotterdam, Utrecht, The Hague), in the age range 0-21 years. Children were included into Dutch, Turkish, and Moroccan groups if both biological parents were born in the Netherlands, Turkey or Morocco, respectively. Children with known growth disorders and those on medication known to interfere with growth were excluded. Children were measured according to protocol by trained staff in Well Baby Clinics, in school health care and at schools. In these representative samples, body mass index (BMI) was compared with the International Obesity Task Force (IOTF) standard (2). The percentages of boys and girls aged 2-20 years exceeding the IOTF age- and sex specific cut-off points for overweight and obesity were calculated (figure). Average overweight (obesity) prevalences across age for Turkish boys and girls were 23.4% and 30.2% (5.2% and 7.2%), for Moroccans 15.8% and 24.5% (3.1% and 5.4%), for Dutch in the large cities 12.6% and 16.5% (1.6% and 2.8%), and for the remaining Dutch children 8.7% and 11.3% (0.8% and 1.4%). For all groups of children living in the large cities, we found significant associations between overweight and ethnicity, parental education (negatively), and gender (positively for girls). The effect of parental education vanished when the relation between education and overweight was corrected for ethnicity and gender.

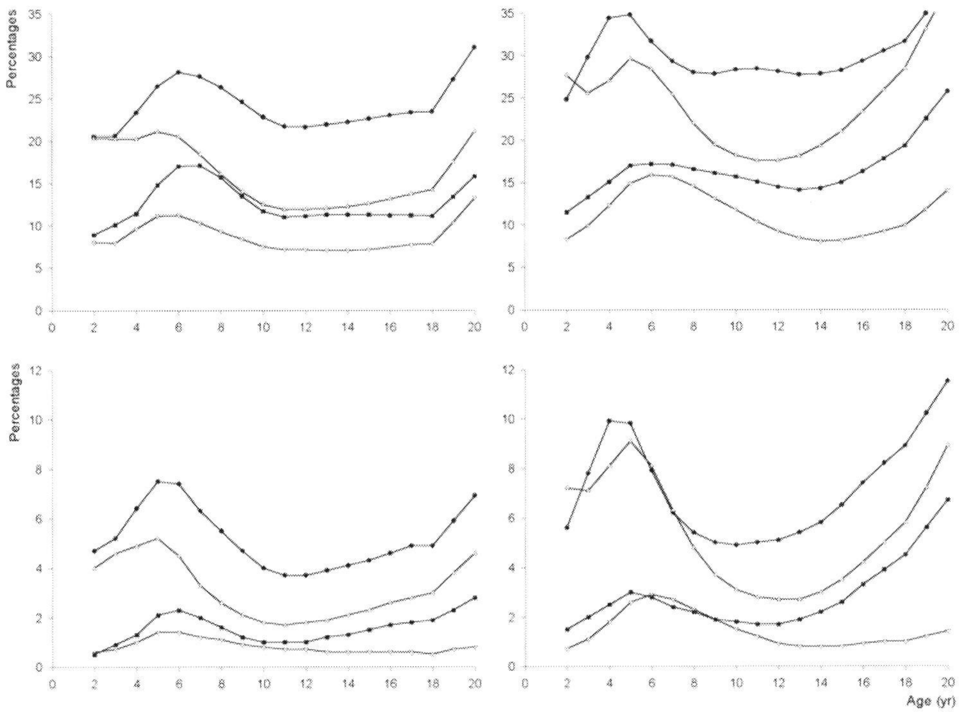

Figure 1. The percentages boys and girls aged 2-20 years, with overweight (top) and obesity (bottem) according to the international standard. • Turkish origin Δ Moroccan origin, ▪ Dutch origin living in the large cities, ∇ Dutch origin living in the other parts of the Netherlands.

Comment

This study shows high prevalence of overweight and obesity in all children, even more so in Turkish and Moroccan children. The high prevalences of overweight and obesity at all ages, but particularly in urban areas and especially the peak between 4-7 years of age, are alarming and call for appropriate interventions. This peak indicates that overweight prevalence for older children may rise further in the coming years. The sex difference is obvious, particularly in the Moroccan group; girls have higher prevalences than boys. It is unclear whether the difference between Turkish and Moroccan children is due to genetic or to cultural factors. Both prevalences are comparable to the alarming United States data (2). Nation-wide, in Dutch children we found a twofold increase in overweight since 1980. Obesity prevalence even tripled. The present Dutch overweight prevalence is similar to that in the United Kingdom (1994) (3).

Overweight is generally associated with a sedentary lifestyle and ingestion of energy-rich food. The excess in overweight in Turkish and Moroccan children might be partly explained by such factors but also by cultural norms that do not recognize obesity, since i.e. in both Morocco and the Netherlands, 52% of the Moroccan women were described being overweight and 22% obese (4-7). Changing cultural norms that do not recognize obesity and the high intake of carbohydrates are the main goals of prevention in Morocco (8).

In conclusion, the overweight and obesity prevalences call for specific culturally embedded prevention strategies, for all children living in urban areas and even more so in Turkish and Moroccan children, to avoid large pressure on future health care caused by obesity related disorders.

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Chapter 10

Worm plot: a simple diagnostic device for modelling growth reference curves

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Abstract

The worm plot visualizes differences between two distributions, conditional on the values of a covariate. Though the worm plot is a general diagnostic tool for the analysis of residuals, this paper focuses on an application in constructing growth reference curves, where the covariate of interest is age. The LMS model of Cole and Green is used to construct reference curves in the Fourth Dutch Growth Study 1997. If the model fits, the measurements in the reference sample follow a standard normal distribution on all ages after a suitably chosen Box-Cox transformation. The coefficients of this transformation are modelled as smooth age-dependent parameter curves for the median, variation and skewness, respectively. The major modelling task is to choose the appropriate amount of smoothness of each parameter curve. The worm plot assesses the age-conditional normality of the transformed data under a variety of LMS models. The fit of each parameter curve is closely related to particular features in the worm plot, namely its offset, slope and curvature. Application of the worm plot to the Dutch growth data resulted in satisfactory reference curves for a variety of anthropometric measures. It was found that the LMS method generally models the age-conditional mean and skewness better than the age-related deviation and kurtosis.

Introduction

The last decade has witnessed an upsurge in methods for constructing age-related reference curves. See the comparison by Wright and Royston (1) for an overview. The major task in centile construction is to smooth the reference distribution in two directions simultaneously, between age and within age. Though this problem can be solved in a variety of ways, all approaches need to specify the amount of smoothness that provides a reasonable trade-off between parsimony of the curves and the fidelity to the data. Different choices lead to different reference values and to dissimilar appearances of the curves. It is therefore sensible to use diagnostics that guide the choice of smoothness parameters in fitting a particular set of data. The present paper introduces a simple, general and flexible graphical method, termed worm plot, to support such modelling decisions.

The method can be used in situations where smoothing within age relies on a theoretical distribution. For example, the LMS method (2,3) assumes that the reference distribution at a given age is normal after a Box-Cox transformation. Other possibilities include normalizing transformations like the shifted log-function (4), and other distributions like the Johnson distribution (5). The worm plot can be applied to other transformations and distributions, but this paper focuses on the use of diagnostics in conjunction with the LMS method.

The text introduces the Fourth Dutch Growth Study, and then briefly reviews the LMS model and some diagnostic tools. Next, we introduce the worm plot, highlight its role in modelling reference curves, and apply it to the Fourth Dutch Growth Study. Finally, the text discusses some choices in the worm plot, and its relation to other methods for choosing smoothness parameters.

Fourth Dutch Growth Study 1997

The Fourth Dutch Growth Study (6,7) is a cross-sectional study that measures growth and development of the Dutch population between ages 0 and 21. The study is a follow-up to earlier studies performed in 1955 (8), 1965 (9) and 1980 (10), and its primary goal is to update the 1980 references. Children with diagnosed growth disorders, those on medication known to interfere with growth, and those without a West European parent were excluded from the population definition. Like the previous studies, the sample was stratified by province, municipal size, sex, and age. The planned sample size was equal to 16,188, and based on the objective to detect at least a 1.8 cm final height difference between the 1997 and 1980 studies with a power of 99%. Age groups were chosen as follows: 6 age groups in year 1, 4 in year 2, 2 in year 3, 3 over the period 3-8, and 2 per year between ages 9 and 20. The age group interval of girls older than 17 years was a year instead of a half year. The realized sample size was n=14,500. Table 1 contains the composition of the sample.

Table 1. Sample size of the Fourth Dutch Growth Study 1997 (Dutch children) by age and sex.

Age	Boys	Girls
0-1	1219	1219
1-2	807	797
2-3	464	454
3-4	295	314
4-5	84	84
5-6	134	137
6-7	66	63
7-8	142	140
8-9	110	108
9-10	334	320
10-11	350	366
11-12	367	364
12-13	381	395
13-14	432	470
14-15	414	392
15-16	407	400
16-17	355	240
17-18	350	183
18-19	333	217
19-20	271	172
20-21	153	171
21-22	14	12
Total	7482	7018

The study measured, amongst others, height, weight, and head circumference. Until the age of two, length of infants was measured to the nearest 0.1 cm in the supine position. A 'microtoise' was used to measure height of children older than 2 years. Children younger than 4 years were measured by 24 Well Baby Clinics during the regular periodical health examination. Children between the ages of 4 and 9 were measured by 25 Municipal Health Services during regular health assessments. Older children received a personal invitation based on a stratified sample from the Municipal Register Office. Non-response (children who refused to show up at the health clinic or refused a measurement) varied between 20% in ages of 11 to more than 60% in those over age 17. Of a random sample of nonresponders (n=230), 170 returned a questionnaire. No significant differences from the study sample were found.

In order to obtain a sufficiently large sample, additional measurements were done at high schools, universities, a youth festival, and during medical examinations for joining the army. No statistically significant differences in height were found between the original and additional sample. The distributions of the combined sample for age, sex, municipal size, family size and child education were similar to national figures obtained from Statistics Netherlands (11). The only exception was geographical region for girls over age 18. A weighted analysis, beyond the scope of this paper, was performed to correct the height references for this effect.

LMS model

The LMS method (2,3) describes a variable *y* as a semiparametric regression function of a time-dependent variable *t*, so that the distribution of *y* changes gradually when plotted against *t*. The distribution is summarized by three time-varying natural spline curves: the Box-Cox power that converts *y* to normality (L), the median (M), and the coefficient of variation (S). Let L(*t*), M(*t*), and S(*t*) stand for the value of the L, M, and S curves at age *t* for a given LMS model. The standard deviation score z of a particular measurement *y* at age *t* can be computed as

$$z = ((y/\,M(t))^{L(t)} - 1)/L(t)S(t), \qquad \text{if } L(t) \neq 0 \qquad \text{or}$$

$$z = \log(y/M(t))/S(t), \qquad \text{if } L(t) = 0$$

The number of effective degrees of freedom (EDF)(12) is a convenient parameter that expresses the amount of adjustment necessary for smoothing a set of data. In the LMS model, the smoothness of the L, M and S curves is characterized by three scalar EDF-parameters: E_L, E_M and E_S. An EDF of zero constrains the entire curve to a given value, and an EDF of 1 corresponds to a constant value whose location is to be estimated from the data. An EDF of 2 yield a straight line, while larger EDFs allow for increasingly more flexibility in the fitted curves. Note that this definition of EDFs may differ from that of other authors, as EDFs are strictly not defined for values less than 2. Also, sometimes EDFs are sometimes presented reduced by one, so that the EDF for a straight line is 1 rather than 2. Cole and Green argued that the distributions of E_L, E_M and E_S in the LMS model are largely independent of each other, implying that one EDF can be optimized while fixing the other two.

In the following, we will use an abbreviated notation for LMS-models as 'LMMSX', where 'L' stands for E_L, 'MM' for E_M, 'S' for E_S, and where 'X' is a transformation option (‘space’ if none, 'R' if rescaled, 'P' if power transformation). Thus, model 4096R has E_L=4, E_M=9, E_S=6, with the rescale option set. Transformation options are a specific feature of the LMS program that will transform the time axis. The rescale transformation (‘R’) fits the LMS model on a rescaled time axis that stretches periods of rapid growth (for example, infancy and puberty), and that compresses periods with lower growth velocities (mid-childhood or adulthood). In effect, the distribution is allowed to change more rapidly at locations where the M curve is steep. After fitting in transformed time, the results are scaled back to the original time scale. The power transform (‘P’) option allows the user to specify the two parameters (offset and power) to rescale the time axis. Cole *et al.* (13) describe these options in more detail. The judicious use of the options may substantially improve the fit.

Diagnostics

For a given choice of E_L, E_M and E_S, the LMS program maximizes the penalized likelihood. Several types of diagnostic skills and tools are helpful for inspecting the quality of the solution:

- *Visual inspection of the shape of the reference curves.* Experienced researchers may recognize the appropriateness of a given set of reference curves based on subtle features in the shape, like a 'pubertal belly' in cross-sectional data. In general, substantial exposure to reference curves is needed to develop the necessary skills.
- *Centiles plotted onto the individual data points.* This type of plot is useful for inspecting outliers and for detecting gaps in the data and gross errors in the model, but its resolution is too limited to be helpful in choosing among different models. The measurements can be visualized in both the original and in the SD scale, but the latter is often clearer.
- *Empirical and fitted centiles plotted on top of each other.* This is an old and quite accurate technique in which the observations are divided into age groups. Empirical centiles are computed for each group, and these are plotted together with the fitted curves. If everything is right, the fitted curves should be close to the point estimates (i.e. within sampling error). Various choices are possible for the vertical scale (raw, standardized for mean and/or standard deviation). A disadvantage of the raw data plot is that if the standard deviation changes with age, the same distance means different things at different ages. Van Wieringen (14) pioneered a standardized graph under the heading of 'graphical graduation'. Care is needed in computing extreme percentiles, as some interpolation is needed. The algorithms implemented in SPSS and SAS can give odd results (mostly estimates that are too wide, irrespective of the interpolation algorithm), and we prefer the S-plus function *quantile()* for this purpose. As the display does not contain individual observations, it may be insensitive to subtle deviations between the fitted and empirical distributions, especially if the number of centiles is small.
- *Observed and expected counts.* Healy *et al. (15)* suggested to compare the observed and expected frequencies of observations within defined centile and age groups. This can only be done if one assumes a distribution of the measurements for each age group. One must choose cut points for centile and

age groups, thus leading to somewhat arbitrary comparisons. The Kolmogorov-Smirnov test and the Q-Q plot, both described below, evade the choice of centile cutpoints, and thus compare the entire observed and expected age-related distribution.

- *Statistical tests.* If the distribution of the measurements is known, a statistical test can be used to test the fit of the solution. In the LMS model, z should be distributed as N(0,1) at all ages. Normality at different age groups can be checked by means of, for example, the Shapiro-Wilk W test. This test is sensitive in picking up any skewness, but is less powerful in detecting kurtosis (16). For other distributions, one could apply a Kolmogorov-Smirnov test. A disadvantage of tests in general is that they do not tell how the empirical and theoretical distributions differ. Techniques based on statistical significance may overfit the curves in large samples. Purists might say that the application of inferential tests for modelling does not comply with the orthodox Neyman-Pearson criteria (since the same data are repeatedly used), and the interpretation of non-significant tests as evidence for the model is not without problems (17).
- *Quantile-quantile plot (Q-Q plot) of the z-scores.* Q-Q plots (18) can be applied if the measurements are supposed to follow a known distribution. The display plots the quantiles of the theoretical distribution (on the horizontal axis) against those of the empirical distribution (on the vertical axis). The Q-Q plot for normal data, also known as the normal probability plot, is best known, but it can be adapted to other distributions. The plot yields insight into structural characteristics (for example, skewness, kurtosis) of empirical deviations from the assumed distribution. In its detrended form, the Q-Q plot is very sensitive to subtle deviations (19). Detrended means that each empirical quantile is subtracted from its corresponding unit normal quantile. As will be demonstrated below, the use of the Q-Q plot as a global diagnostic is limited though.
- *Worm plot.* The worm plot consists of a collection of detrended Q-Q plots, each of which applies to one of successive age groups. The vertical axis of the worm plot portrays, for each observation, the difference between its location in the theoretical and empirical distributions. The data points in each plot form a worm-like string. The shape of the worm indicates how the data differ from the assumed underlying distribution, and when taken together, suggests useful modifications to the model. A flat worm indicates that the data follow the assumed distribution in that age group.

Note that the application of the latter four approaches require distributional assumptions, whereas the first three do not. In practice, one will typically apply a combination of diagnostics as in, for example, the recent paper by Royston and Wright (20).

Illustration

Figure 1 contains the conventional Q-Q plot and the detrended Q-Q plot for a normal distribution of z scores of over 7000 boys in the fourth Dutch Growth Study 1997. All ages are combined here. The detrended plot on the right contains the 95% confidence interval of the unit normal quantiles. For a given quantile z with associated probability p and a sample size n, the 95% confidence interval is computed as $\pm 1.96 * f(z)\text{-}1\sqrt{(p(1\text{-}p)/n)}$, where $f(z)$ is the normal density function (21). Due to scarce data, the interval becomes broader towards the extremes, so in the tails larger differences between theoretical and empirical quantiles are tolerated. Except for the area below –2 SD, the empirical quantile points are all located near the main diagonal. The marginal z scores, that is the z scores of all age groups combined, thus closely follows a normal distribution. However, this apparent fit does not imply that the model even remotely fits the data.

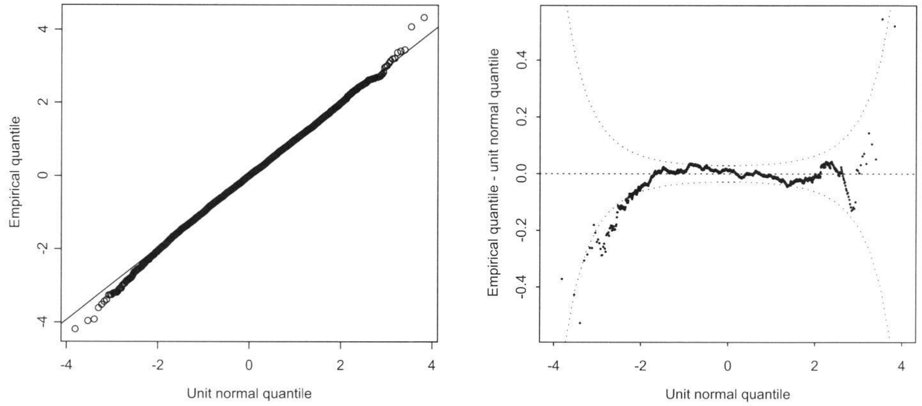

Figure 1. Conventional (left) and detrended QQ-plot (right) of the *z*-scores of height of Dutch boys (all ages combined, LMS model 0051R). The detrended Q-Q plot improves upon the resolution of the conventional display, and includes 95% confidence intervals. Both figures convey the misleading message that model 0051R fits reasonably well.

Figure 2 is a worm plot of the same data. The data are split into 16 age groups of equal size, and the relevant computations are done in each group separately. The exact age boundaries are given in each panel of the plot. Figures 1 and 2 provide dramatically dissimilar views on the same data. In fact, figure 2 shows that the model fits badly at almost all ages. The only reasonable fit occurs in age group 9.1-10.4. For other ages, the worms move around in all directions, indicating the existence of gross errors in the fit of the statistical model. The modelling problem is now to 'tame the worms', so that each of them becomes as flat as possible and aligns up neatly along the horizontal axis. The 95% confidence interval gives an impression of the sampling variation, and delineates the region where the worm should be located most of the time if the empirical and theoretical distributions agree.

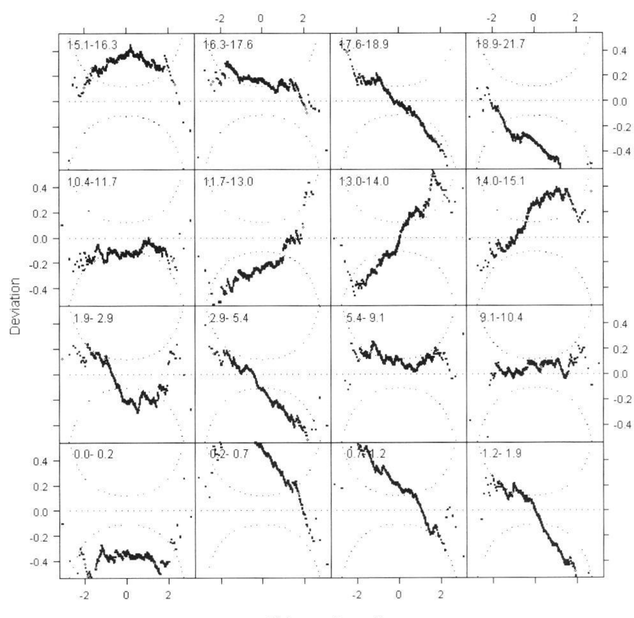

Figure 2. Worm plot of the *z*-scores for height of Dutch boys (LMS model 0051R, same as figure 1). The plot consists of detrended Q-Q plots in 16 age groups of equal size, ordered from the lower-left panel to the upper-right panel. Model 0051R fits badly in almost all ages

The shape of the worms communicates the type of misfit between model and data. Table 2 summarizes several aspects of the distribution. Each shape describes a different aspect of the model fit.

Modelling strategy

The number of EDFs in figures 1 and 2 is equal to $E_L = 0$, $E_M=5$ and $E_S=1$ for the L, M and S curves, respectively, compactly written as 0051R. This model corresponds to a normal distribution of constant variation and a moderate spline for the M curve.

Table 2. Interpretation of various patterns in the worm plot.

Shape	Moment	If the	Then the
Intercept	Mean	worm passes above the origin,	fitted mean is too small.
		worm passes below the origin,	fitted mean is too large.
Slope	Variance	worm has a positive slope,	fitted variance is too small.
		worm has a negative slope,	fitted variance is too large.
Parabola	Skewness	worm has a U-shape,	fitted distribution is too skew to the left.
		worm has an inverted U-shape,	fitted distribution is too skew to the right.
S-curve	Kurtosis	worm has an S-shape on the left bent down,	tails of the fitted distribution are too light.
		worm has an S-shape on the left bent up,	tails of the fitted distribution are too heavy.

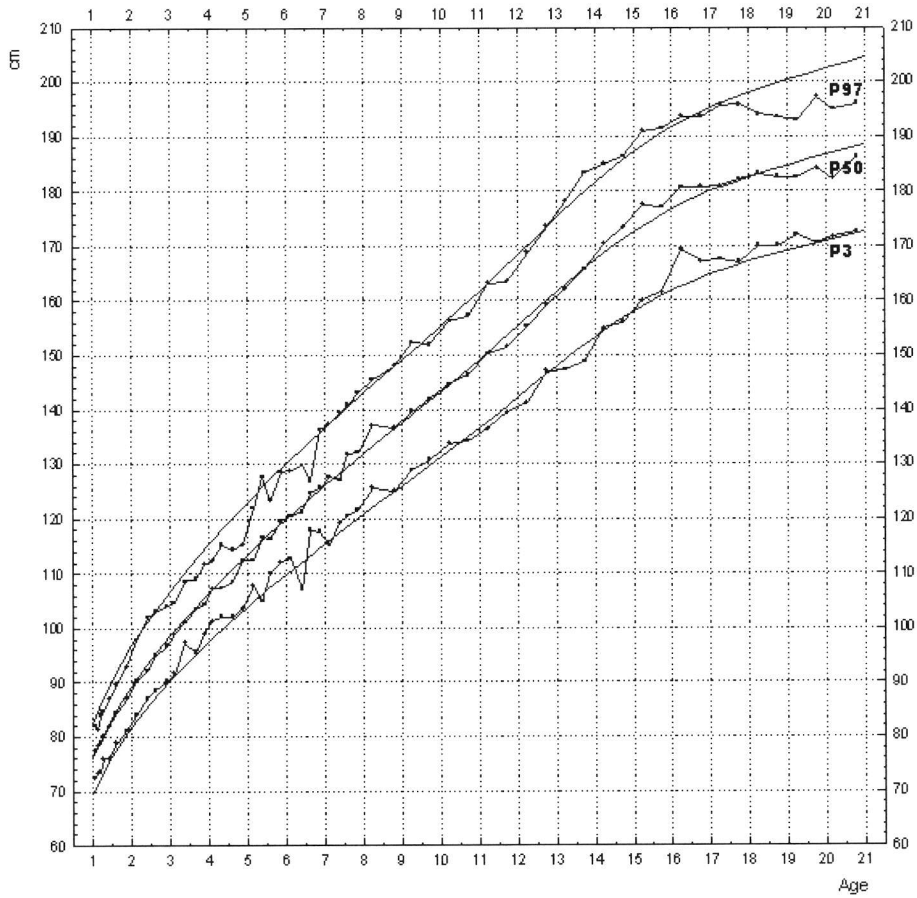

Figure 3. Raw and fitted percentiles for height of Dutch boys (all ages combined, LMS model 0051R).

Figure 2 suggests that the model is too inflexible for the data. This is confirmed in figure 3, which draws the raw and fitted percentiles on the same diagram. The P_{50} does not follow the raw median and misses the bend at about 15-16 years. Until the age of 6 and above the age of 17, the P_3 and P_{97} reference curves are too wide, while they are too narrow during puberty.

Cole provides guidelines on obtaining optimal values for E_L, E_M and E_S (see the documentation of the LMS Fortran program in ftp//:ftp.statlib.edu/lms). Starting with values $4 \leq E_M \leq 6$ and E_L=E_S=1, his strategy is to optimize E_M first by increasing E_M progressively by 1 until the change in the penalized likelihood becomes small. Let this change be denoted as the *D-statistic*, defined as $D(v,w)$=2(l(w)-l(v)), where v is the more restrictive model nested inside model w, and where l(v) and l(w) are the corresponding penalized log likelihood values. It is common to assume that D has an asymptotic χ^2-distribution with d degrees of freedom, where d is the number of additional free parameters in the less restricted model (12). A typical cut-off point of D is 2, but the precise choice depends also on sample size, where larger samples need larger cut-off points. The final decision on the E_M-parameter will depend on the appearance of the M curve. The process is repeated for the S and L curves, fixing the previous optimal values of E_M and E_S. Cole suggested to skip model with $E_L = 2$ and $E_S=2$ in order to evade 'silly values at the extremes'. In addition to the M step, one could experiment with alternative transformations of the time axis, which may help to reduce the complexity of the M curve.

This conditional optimization approach is simple and relatively easy to perform. The sequence of steps (first M, then S, and then L) is sensible because the M curve describes the most important variation, while the influence of L is relatively small. Subjective elements in the procedure include the choice of the cut-off point and the visual assessment of the M curve. With sample sizes around 7,000, we frequently found that a change of say 5 or 10 units did not appear to have any influence on the shape of the curves. It sometimes happened that increasing E_M introduced spurious wiggles.

It is often difficult to see what actually happens to the fitted curves when an EDF changes. Also, it is hard to assess how well the curves actually fit the data. The worm plot can be used in a visual analogue to the conditional optimization strategy, and remedies these two deficits. This is done by the following steps:

- increase E_M such that each worm passes through the origin of the plot;
- then, increase E_S such that each worm has more or less a zero slope;
- then, increase E_L such that quadratic shapes (U-shapes) disappear.

By aligning worm plots of two models side by side, it is easy to see at what points the LMS optimization changes the curves. This requires the same cognitive skills as needed for the kids' game 'find the 10 differences between two pictures'. The worm plot gives a visual impression of the fit between data and model at different ages.

Modelling the Fourth Dutch Growth Study 1997

Figure 4 is the worm plot for model 0101R for the Dutch male height data, thus where E_M has increased from 5 to 10. The vertical distance between worm and origin is now small everywhere, which indicates that the M curve does a reasonable job in modelling mean height. Increasing E_M to 11 did not appreciably improve upon the display, so $E_M = 10$ was considered an appropriate choice.

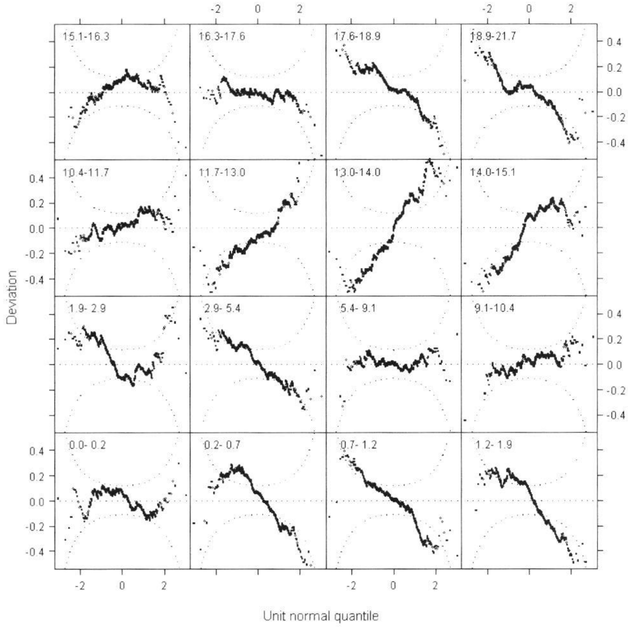

Figure 4. Worm plot for height of Dutch boys (LMS model 0101R). Worms are close to the origin, indicating a reasonable fit of the M curve.

Figure 5 is a similar display for models with E_S=6 instead of E_S=1. The worms flattened in comparison to figure 4, signaling that the new S curve is a better description of the differences in height variation across ages. Differences between models 0106R and 0107R were deemed insignificant, so E_S=6 was taken as the final choice.

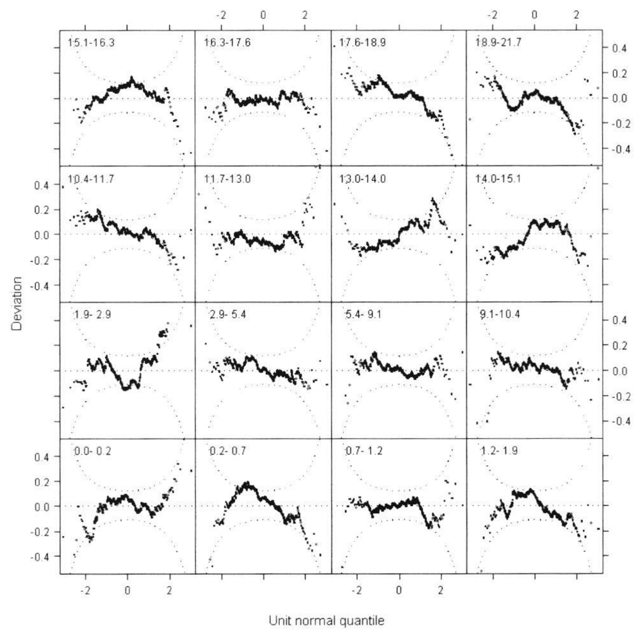

Figure 5. Worm plot for height of Dutch boys (LMS model 0106R). Worms are relatively free of linear trend, indicating a reasonable fit of the S curve.

The second (9) and third (10) Dutch growth studies found a skewed conditional height distribution during the first years of puberty. Does this also hold in the present data? Several values for E_L (0, 1, 3, 4) were tried, thus correcting for age-related skewness. The overall impression is that the effect of increasing E_L is quite small. Figure 6 displays the worm plot corresponding to model 4106R. This model fits slightly better than the normal model with E_L=0. If there were a difference of only one degree of freedom between both models, we would prefer the more complex model over the simpler normal model. However, here the models differ by four degrees of freedom. The worm plots for models with E_L=1 and E_L=3 lie in between those in figures 5 and 6, and the transitions are small. Figure 7 is a diagram of the raw and fitted percentiles for models 0106R and 4106R. It appears that the effect of increasing E_L is very small. Note that there is a rising linear trend in height after age 19. This reflects the strength of the spline approach compared to a parametric curve (for example, the Jolicoeur model) which assumes that height reaches an asymptote in adulthood. Model 0106R was used to update the Dutch growth references, and the official height reference values (6) are based on this model.

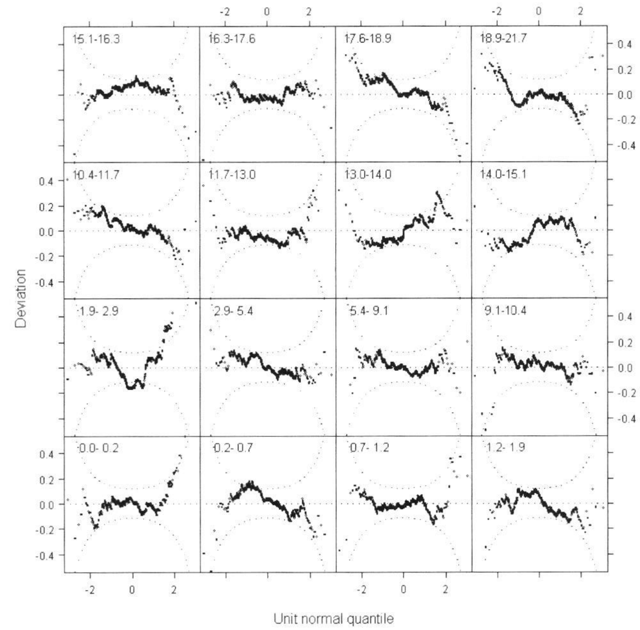

Figure 6. Worm plot for height of Dutch boys (LMS model 4106R). Adding skewness parameters hardly improves the fit.

Properties

Shape estimates

It is possible to quantify the basic features of the worm shape. Polynomial regression of the empirical on the theoretical quantiles gives numerical estimates of various aspects of the discrepancy between the observed and theoretical distributions. Suppose that the results are scaled according to an equation of the form $Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \beta_3 X^3$, where Y denotes the vector of detrended ordered observations and where X denotes the vector of quantiles. The idea is that the shape coefficient β_0 measures the amount of misfit of the M curve, β_1 measures the amount of misfit of the S curve, and so on. The correspondence between the β's and the moments of the empirical distribution relates to the inverse Cornish-Fisher expansion (22,23). Some statistical literature suggests that β_0 is equal to the difference of the theoretical and empirical means, and that β_1 measures differences in variation (24,25). The inverse Cornish-Fisher expansion suggests that β_2 and β_3 measure differences in skewness and kurtosis, respectively, but the precise relation between these coefficients and more common measures of skewness and kurtosis is not yet clear. The HRY method (15) implicitly relies on these properties, as it describes the form of the age-conditional distribution as polynomial functions of the unit normal quantiles, as above. Healy *et al.* note that increasing the degree of these polynomials from 1 to 2 allows for skewness, and increasing it to 3 allows for skewness and kurtosis.

Shape coefficients can be used for quantitative assessments of model fit. Coefficients of the same type (for example, all β_0) can be compared across models to see the effect of model alterations. Shape coefficients β_0 and β_1 are approximately on the same scale and can be compared with each other. Coefficients β_2 (quadratic) and $\beta 3$ (cubic) are on smaller scales. To give some idea of their interpretation, we categorize solutions where the absolute values of β_0 or β_1 are in excess of 0.10 as misfits. For β_2 we use a threshold of 0.05, and for β_3 we take 0.03.

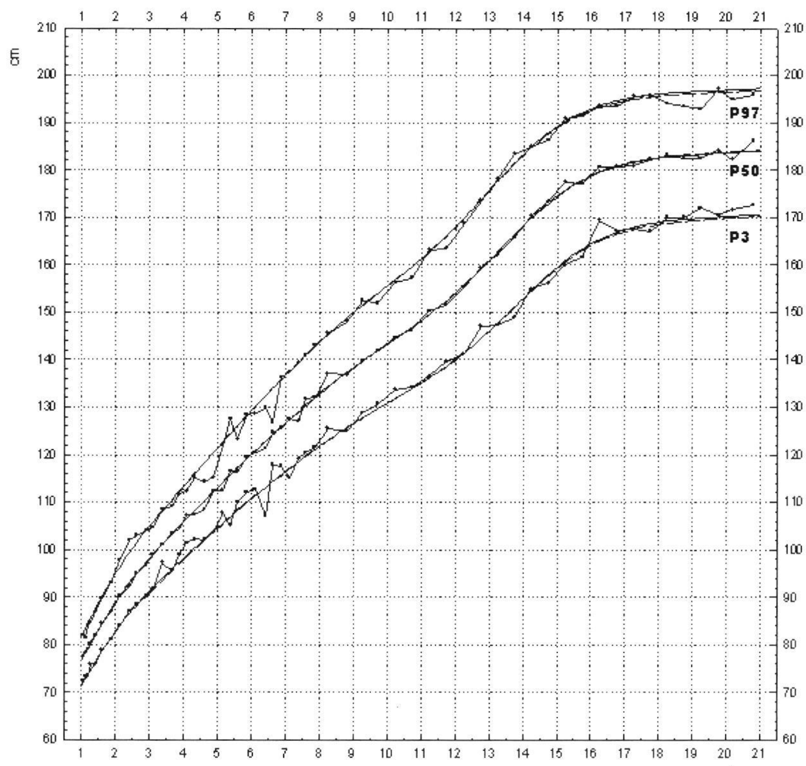

Figure 7. Raw and fitted percentiles for height of Dutch boys (LMS models 0106R and 4106R). Model 0106R is the official 1997 height reference update.

Choices in the worm plot

Some details of the worm plot, like the number of age groups and the choice of scales, have not yet been discussed. When restricted to a square layout, convenient choices include the 3x3, the 4x4 and the 5x5 plotting grid, thus defining 9, 16, and 25 age groups respectively. In general, increasing the number of age groups provides a more detailed, but less stable plot. As a rough guideline, at least 200-300 points per group are needed for a reasonably stable picture. In our experience, using 9 age groups might obscure important deviations from normality, like those concerning the whole age range as in figure 1. On the other hand, the display becomes somewhat crowded if 25 or more groups are formed, especially if side-by-side comparisons are being made. In addition, the number of points can become quite low. The number of 16 groups seems to be a good compromise, but it is also useful to experiment with other resolutions.

The scale of the y-axis was chosen as the range -0.5 to +0.5 SD for all panels. This range is a compromise between an adequate display of the volatility of the worms and the objective of minimizing the number of points outside the active plotting area. The setting may occasionally produce entire empty panels if the model fits very badly.

It is sensible to choose the cut-off points on age such that each group approximately has the same expected increment in the measurement. It is, however, erroneous to directly cluster heights into groups, since that would inadvertently destroy the age-conditional normal distribution. We therefore divided the observations into groups of equal size. Since groups at higher velocities are sampled more often, this procedure approximates the objective of 'same expected increments'. In this way, the mean height increment per age group varies between 7 cm (ages 0.0-0.2 years) to 22 cm (ages 5.4-9.1 years) to 2 cm (above 16 years). We experimented with non-overlapping and overlapping age groups, where the observation appears in two adjacent panels, and found that either possibility led to similar model choices. An advantage of overlap is that the display is relatively insensitive to the exact location of the boundary points. A disadvantage is that it cannot be handled so easily with summary statistics like those that were recently proposed (26). All plots in this paper were made with non-overlapping groups, so every observation appears just once.

Figure 8 is an example of a *cubine plot*, a stylized version of the worm plot. ‘Cubine’ stands for ‘cubic line’, that is, the line predicted by the four-parameter polynomial model of section “shape estimates”. The interpretation of the cubine is identical to that of the worm. The 95% confidence interval of the cubine is also plotted. One could check whether the cubine is located within the interval. If it is, this suggests that differences between the empirical and theoretical distributions for that age group is due to random variation.

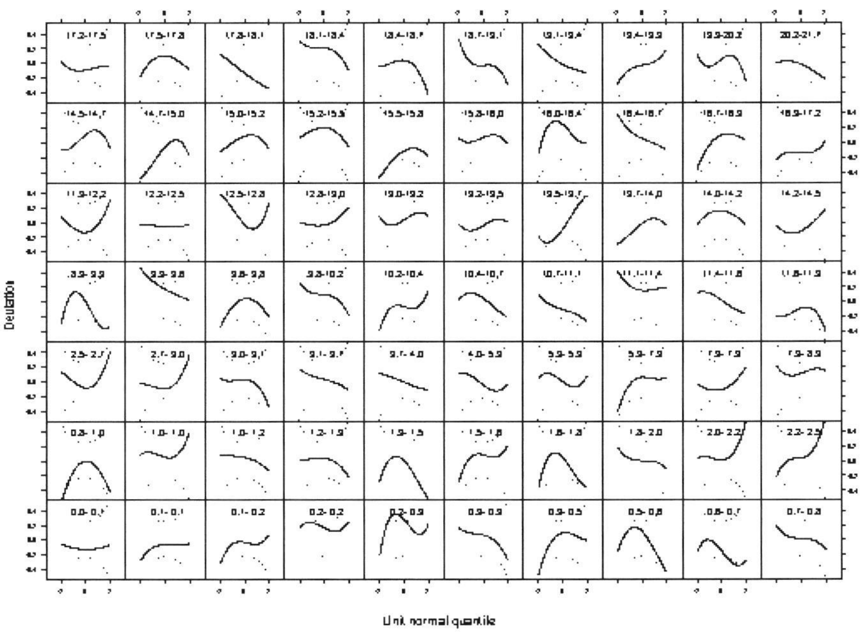

Figure 8. Cubine plot with 70 panels for height of Dutch boys (LMS model 0106R).

The cubine plot is useful to assess finer details in the case that the number of panels is large, i.e., for smaller age groups. For example, we were concerned that the rather large height increment in the worm plot in ages 5-9 years would obscure important deviations. The corresponding cubines for the ages in figure 8 are quite regular, indicating that the model fits well here and that the fit is independent of the age grouping. If certain shapes repeat in successive panels, for example, three consecutive U-shaped cubines, such repetitions could be used to detect detailed misfits. Cubines could be used instead of worms, but the view on the raw data will be lost. Also, they will not display shapes more complex than the cubic.

Relation with the D-statistic

The application of the worm plot may lead to model choices that differ from those obtained by the difference between penalized likelihood values. For height, the worm plot usually suggests larger cut-off points in terms of likelihood differences, thus resulting in models with fewer parameters. For example, the likelihood difference between models 0101R and 0111R is equal to D(0101R,0111R)=27.9, while D(0106R, 0107R)=12.0. In both cases the more complex model is a statistically significant improvement over the simpler one, yet the worm plots do not indicate noticeable differences between the solutions. Employing a cut-off point of $D \leq 10$ would result in model 1137R, and a cut-off of $D \leq 5$ would produce model 1169R. The latter model clearly overfitted the data and produced wiggly curves.

One might be inclined to think that the worm plot is less sensitive than the *D-statistic*, thus leading to overly simplistic models. Though both the worm plot and the *D-statistic* assess similar aspects of the model fit, this conjecture is inaccurate. For example, in modelling the S curves for head circumference, the worm plot indicates appreciable changes in the conditional circumference distribution, while the *D-statistic* is quite small (for example, *D*(0093R,0094R)=2.8, *D*(0094R,0095R)=9.0). Thus, the worm plot is not simply a coarse version of the D-statistic, but provides a different and more informative view on the data.

Table 3. Optimal LMS models for various types of reference diagrams in the Fourth Dutch Growth Study, and the total of misfits (out of 16) for each polynomial shape.

Measure	**Ages**	**BOYS**					**GIRLS**				
		Model	**Misfits**				**Model**	**Misfits**			
			b0	b1	b2	b3		b0	b1	b2	b3
height for age	0-21	0106R	0	1	0	0	0105R	0	1	0	0
weight for age	0-21	4085R	0	5	0	2	4086R	0	4	0	2
weight for height	0-16	3074R	0	5	2	3	3074R	0	1	0	0
head circumference for age	0-21	0095R	0	5	4	7	0074R	1	6	2	7
body mass index for age	0-21	5135P	0	3	0	2	5116P	0	3	0	0

Note: Using a power transformation for body mass index with offset 0 and powers 0.33 (boys) and 0.25 (girls).

Table 3 gives an overview of the final models fitted for the Fourth Dutch Growth Study, as well as the total of misfits for each basic shape, as defined in section 'shape estimates'. Note that the fit of the mean curve is quite good in almost all cases. An exception is model 0074R for head circumference of the girls. To a lesser extent, this also holds for the quadratic shape. Height curves appear to be relatively easy to fit with the LMS model. The worm plot of weight for age contains clear S-shapes for ages 14-17 years, indicating that the fitted tails might be too thin in this age range. The story of weight for height is somewhat mixed as the curves for the girls fit substantially better than those for the boys. Head circumference appears to have thicker tails than the normal distribution during the first year of life. The fit of the reference values for body mass index (BMI) is quite good.

Conclusion

The worm plot is a diagnostic tool to describe salient features of the age-conditional *z*-score distribution. It aids in finding proper smoothing values for E_M, E_S, and E_L of the LMS method. There is a close correspondence between these smoothing parameters and particular shapes of the worms. These basic shapes can be estimated numerically by polynomial regression. The worm plot assesses whether a particular LMS model leaves any important unexplained structure in the residuals. The LMS model generally adequately describes the median and the skewness of the data, but has more difficulty in modelling deviation. The LMS model assumes that there is not any kurtosis.

The worm plot can be used in conjunction with other methods than LMS. In fact, the normal worm plot can assess the fit of any model based on conditional normality, including a large variety of linear and non-linear regression models. The tool seems especially useful in cases where inspection of marginal normality is misleading, as in figure 1. Using the worm plot in conjunction with the LMS model is particularly instructive since different parameters influence different aspects of the worm. Other growth models that will probably work quite well include the HRY model (15), the fractional polynomial model (20) and the quantile model (27). Chambers *et al.* (21) give general formulas for estimating the confidence intervals, so the worm plot can also be applied to distributions other than the normal. Repetition of shapes in the cubine plot might be investigated in a formal way by computing and testing the autocorrelation of the shape coefficients across age groups.

The summary of the shape estimates in table 3 may act as a rough guideline for users that fit LMS models to other data. One should keep in mind that the results are based on the analysis of one data set. In future studies, it could be useful to quantify and study the variation in optimal EDFs derived from other populations.

Cole (2) remarked that producing centile charts has always been something of a black art. His LMS method combined ideas of the method of Roede and Van Wieringen (10) and Van't Hof *et al.* (28), and paved the way for modern methods that give reproducible results. However, the inner workings of modern centile fitting methods are not so obvious: black art was replaced by a black box. We think that our worms can contribute in opening up this black box, and hope that they provide fertile soil for further development.

Appendix: S-Plus 4.5 function for drawing the worm plot

```
# S-plus 4.5 functions for plotting the worm plot.
# Author: S. van Buuren, TNO Prevention and Health (1999).

read.lms <- function(filename)
{
# function to read the z-scores from the .lms output file generated
# by the LMS software of T.J. Cole (version June 1998)
	lms.par <<- scan(filename, n = 8)
	print(lms.par)
	lms.skip <- lms.par[8] + 2
	read.table(filename, skip = lms.skip, col.names = c("age", "val", "z"))
}

wp <- function(data, layout = c(4, 4), overlap = 0, worms = T, cubines = F, coefsave = F, labels = T,
hor=T, vert=F, ci = T, sub = paste(deparse(substitute(data)), deparse(substitute(overlap))))
# function for plotting the worm plot on the active graphics device
{
	panel <- function(x, y)
	{
		qq <- as.data.frame(qqnorm(y, plot = F))
		qq$y <- qq$y - qq$x
		plot(qq$x, qq$y, type ="n", ylim=c(-0.5, 0.5),xlim =c(-3, 3), lab =c(3, 5, 7), tck=-0.01)
		if (hor) abline(0, 0, lty = 2, col = 1)
		if (vert) abline(0, 100000, lty = 2, col = 1)
		if(worms)
			points(qq$x, qq$y, col = 1, pch = 1, mkh = 0, cex = 0.25)
		if(cubines | coefsave)
			fit <- lm(y ~ x + x^2 + x^3, data = qq)
		if(cubines) {
			s <- spline(qq$x, fitted(fit))
			flags <- s$x > -2 & s$x < 2
			lines(list(x = s$x[flags], y = s$y[flags]))
		}
		if(coefsave) {
			est <- coef(summary(fit))[, 3]
			assign(".est", c(.est, est), frame = 0)
		}
		if (ci) ciplot(sum(!is.na(qq$y)))
	}
	agetext <- function(classes, layout = c(4,4), cex=0.6, dx = 0.06, dy=0.02)
	# function for adding age group text to the worm plot panels
	{
		txt <- apply(format(round(summary(classes)$intervals,1)),1,paste,collapse="-")
		x <- rep((0:(layout[1]-1))/layout[1]+dx,layout[2])
		y <- rep((1:layout[2])/layout[2]-dy,each=layout[1])
		text(x, y, txt, cex=cex)
	}
	assign("panel", panel, frame = 1)
	assign("worms", worms, frame = 1)
	assign("cubines", cubines, frame = 1)
	assign("coefsave", coefsave, frame = 1)
	assign("hor", hor, frame = 1)
	assign("vert", vert, frame = 1)
	assign("ci", ci, frame = 1)
	assign(".est", NULL, frame = 0)
	if(length(layout) == 1) layout <- rep(layout, 2)
	n <- prod(layout)
```

```
        classes <- equal.count(data$age, n, overlap = overlap)
        if(n == 1) form <- ~ data$z
        else form <- ~ data$z | classes
        print.trellis(qqmath(form, layout = layout, aspect = 1, strip = F,
        sub = list(sub, cex = 0.5), xlab = list("Unit normal
                quantile", cex = 0.75), ylab = list("Deviation",
                cex = 0.75), panel = panel))
        if (labels) agetext(classes, layout, cex=0.6, dx = 0.06, dy = 0.02)
        return(list(classes = classes, .est = get(".est", frame = 0)))
}

ciplot <- function(n, level=0.95, lz=-2.75, hz=2.75, dz=0.25){
        #       adds confidence interval to Q-Q plot panel
                z <- seq(lz,hz,dz)
                p <- pnorm(z)
                se <- (1/dnorm(z))*(sqrt(p*(1-p)/n))
                low <- qnorm((1-level)/2)*se
                high <- -low
                lines(z, low, lty=2)
                lines(z, high, lty=2)
}
```

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Chapter 11

General discussion

Introduction

The Fourth Dutch Growth Study has resulted in a large amount of data on a variety of anthropometric measurements. In this chapter the following issues will be discussed: 1) the design of the study; 2) the secular change in height; 3) its consequences for the calculation of target height; 4) secular changes in pubertal development; 5) the rising prevalence of overweight; 6) the clinical use of the growth charts; and 7) implications of our results for society and future research.

1. Design

The Fourth Dutch Growth Study has provided growth charts based on a cross-sectional design, which implies that a large number of children were measured once in a relatively short period of time. Alternative study designs are a longitudinal design (in which a limited number of children are followed from birth to young adulthood) and a semi-longitudinal design (in which various cohorts of children are measured for a number of years, with short periods of overlapping ages to enable curve-fitting for the full growth period). A semi-longitudinal design is particularly useful in a period of fast growth, such as in puberty, when individual children have a different timing of their growth spurt.

Growth charts based on cross-sectional data have several advantages: 1) they provide information on the secular trend; 2) data collection can be carried out in a relatively short period; 3) the sample can be relative large and representative for demographic variables; and 4) age-related phenomenons in different decades can be studied, for example comparison of final height in the different studies.

However, there are also disadvantages of a cross-sectional design. First, theoretically is may be expected that, if there is a secular trend, individual growth curves will cross the centiles or SD lines with advancing age. Based on the trend between 1980-1997, this would be approximately 2 cm per 17 jaar for boys. In clinical practice, however, this appears of little relevance, and a child's growth curve usually stays very close to his SDS position. Another disadvantage is that no information is obtained about growth velocity. The SD lines represent the variation of a biometric variable for each age at a fixed moment.

As mentioned above, growth charts based on longitudinal design provide information on growth velocity, but there are important disadvantages: 1) a long time for follow up is necessary; 2) reference data are already outdated at the moment they are produced; 3) it is expensive and complicated to carry out; and 4) the sample can only be small, while there is a considerable risk of dropouts and consequently insufficient numbers of data to estimate the extreme centiles in the growthchart.

A mixed-longitudinal (semi-longitudinal) design is meant to combine some of the advantages of a cross-sectional design with some of the advantages of a longitudinal design. However, these advantages should be weighed against the additional costs of such design in comparison to those of a cross-sectional design, and the consequences of the lower number of participants. Based on these arguments, we chose for a cross-sectional design, as was also used in the NCHS growth study and many others.

2. Secular change in height

Comparison of the results of the Fourth Nationwide Growth Study with those of the three previous studies (Chapter 2) shows that during a period of 42 years the positive secular growth change has continued. Similar to 1965 and 1980, and already noted in 1880, regional height differences were found, which is remarkable for a small country like the Netherlands (northern children were taller than southern children). The distribution has remained strikingly similar, with a coefficient of variance of approximately 3.8%. Therefore, one can assume that not only the shorter part of the population has shown the secular change, but also the taller part. This is in contrast with observations in Belgium, where the secular change was greater in people with low educational background than in people with a higher education (1).

It is noteworthy that the mean height of Dutch children, adolescents, and young adults has further increased in the years between 1980-1997, while in 1980 the Dutch already belonged to the tallest populations in the world (figure 1A and 1B). The average final height in 1997 was 184.0 cm for 21 years old men (compared to 182.0 cm in 1980) and 170.6 cm for women (compared to 168.3 cm in 1980). For comparison, the last growth references in Sweden, based on longitudinal data, show that 18 year old men had a mean height of 180.4 cm and young women 167.7 cm (all born between 1973-75). Once they were the tallest people in Europe, possibly because their positive secular change was not interrupted by a period of diminished height gain during World War II. Comparison with a previous longitudinal growth study (all born between 1955-58) indicated that also in Sweden a continuing positive secular growth change was present, though relatively small (1.2 cm/decade) (2).

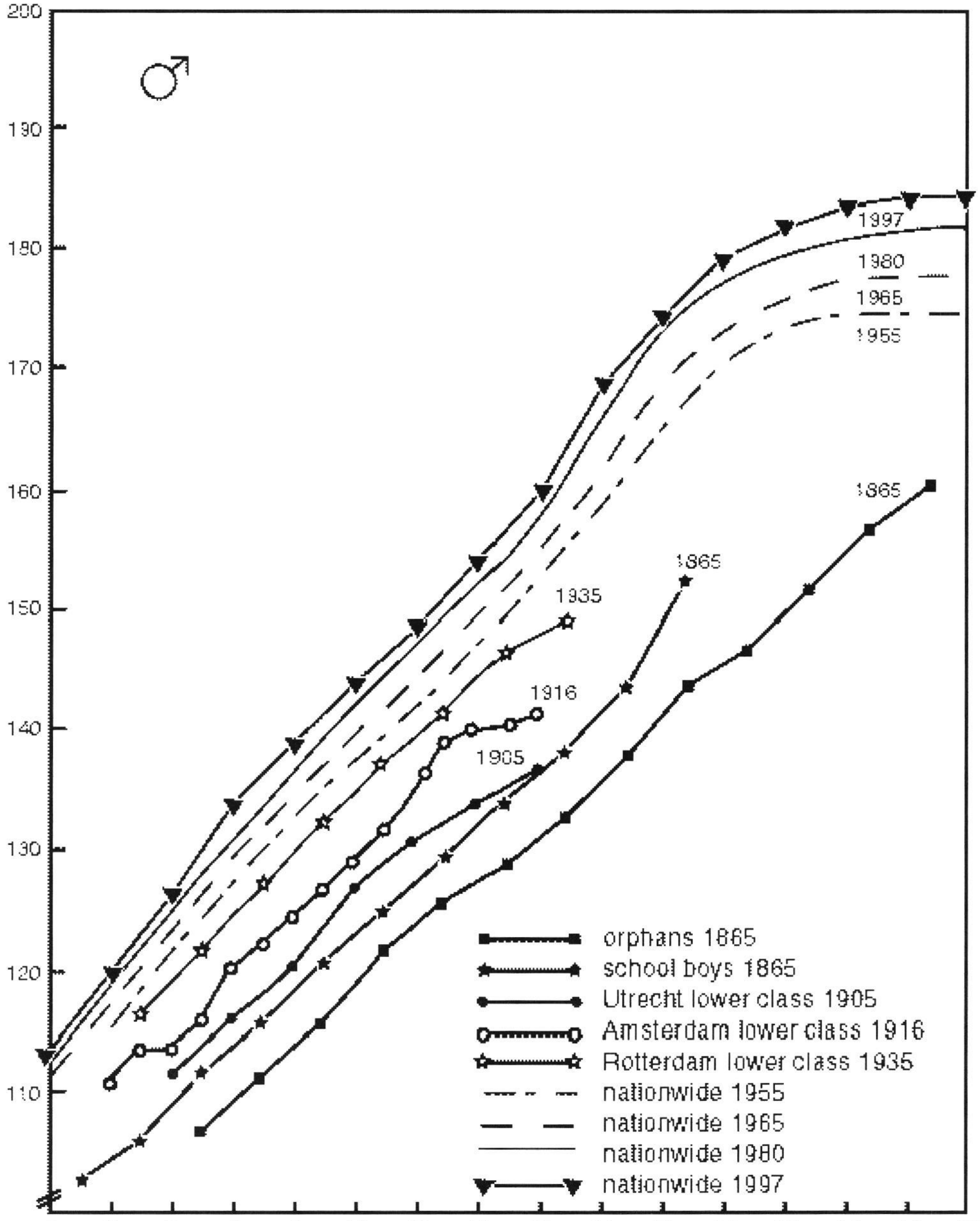

Figure 1A. The positive secular growth change for Dutch boys, illustrated by the mean heights in the Netherlands since 1865. The four nation-wide growth studies; 1955, 1965, 1980, and 1997 are included. (Roede MJ, van Wieringen JC, 1985)

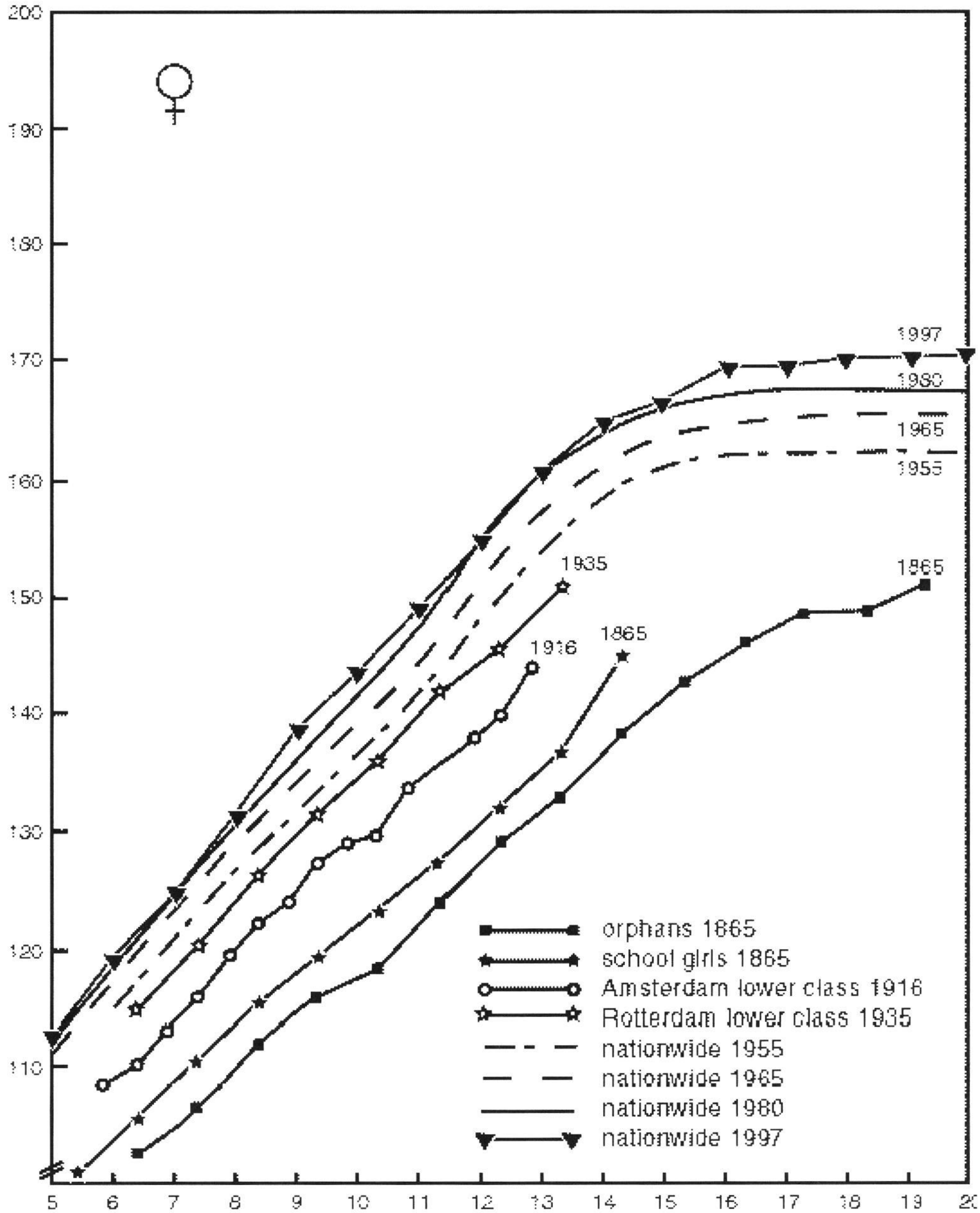

Figure 1B. The positive secular growth change for Dutch girls, illustrated by the mean heights in the Netherlands since 1865. The four nation-wide growth studies; 1955, 1965, 1980, and 1997 are included. (Roede MJ, van Wieringen JC, 1985)

While it is remarkable that there is still a positive secular change in the Netherlands, it has definitely slowed down, from 2.7 cm/decade in the fifties to 1.3 cm/decade in the nineties. On the other hand, this pattern implies that it is very unlikely that average stature has already reached its maximum. Based on the pattern of secular change in the period 1955-1997, one can estimate the expected secular change in the period from 1997 to 2012. This is shown in figure 2. In this figure we plotted the mean final height differences in the last three growth studies compared with the findings in 1955 and we added a future point by extrapolation. The expected increase is then 1.7 cm in 2012 (9.5 cm taller compared to 1955).

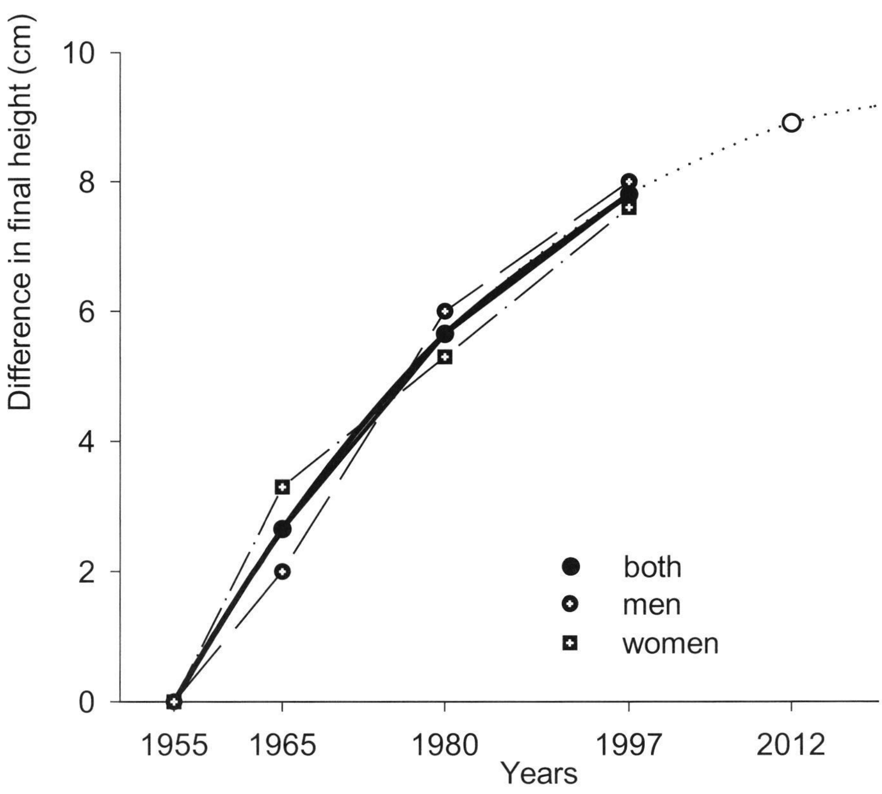

Figure 2. Differences in final height in the 1965, 1980, and 1997 Dutch Growth Studies compared with the 1955 study for men and women. In 1965, 1980, and 1997 was the mean increase in final height 2.7, 5.7, and 7.8 cm compared to 1955, respectively. The dotted line represents the estimated height in 2012 (9.5 cm).

With respect to the cause of secular change, there are mainly hypotheses and few facts. Assuming that growth is determined by genetic factors and environmental conditions, the general idea is that secular change is predominantly caused by an improvement of environmental conditions, including general wealth, living conditions, protein-rich food, better hygiene, and improved child health caused by vaccination programs and new antibiotics. The general increase in weight for height appears to have more effect on stature than on advancing puberty (Chapter 4), so that the net effect on final height would be positive. This would imply that as long as factors that block full expression of the biologic potential are negligible, the population will grow taller until the maximum of its genetic potential is reached. Although environmental conditions may play the major role in the secular change, the observation that tall men are more reproductive than short men points also to a genetic component of secular change (3).

With respect to environmental changes, one could also speculate that pseudo- or phyto-estrogens and hormones, like clenbuterol, in Dutch food might cause a taller stature. However, this appears unlikely because of a number of reasons. Concentrations of such substances are minimal or absent in food, especially meat, and its use is less common in the Netherlands than in other countries. Besides, theoretically the effect of sex hormones might rather inhibit than stimulate growth, while they would be expected to cause an earlier growth spurt and puberty and finally result in a shorter height in young adulthood.

Another environmental factor that is worth discussing is the climate. The Bergmann (1850) theory postulates that mammals in a moderate climate are taller than those in a warm climate, because taller organisms hold more heat. In addition, the theory of Allen (1877) proposed that the colder the climate, the shorter the limbs and arms to protect from loss of heat. In fact, nearby the equator most people are short and going upwards to the North pole and southwards to the South pole people get taller, while at both poles, people are short again with short limbs and arms. This might explain that the effects of a high protein and high fat diet being different in polar regions (the Inuit Eskimo's in the North are short) from tropical areas (the Masai in sub-Saharan Africa are one of the tallest people on earth). In Africa tallness (possibly caused by high protein food) is still compatible with a tropical climate, while it is not in polar regions.

The increase in stature is mainly caused by an increase in leg length, as documented in several countries (4,5). In the three previous national Dutch growth studies no data on body proportions were collected, so we cannot comment on the secular trend with respect to body proportions. If future growth studies would be planned, it is therefore recommended to include body proportion measurements. The major height difference compared to 1980 occurred in childhood and in these years growth mainly depended on increasing leg length. In the first year of life no secular growth change has been found, and no height differences between breastfed and bottle feed children were observed, so the feeding period between 2-10 years seemed to be of more influence on final height than feeding practices in infancy.

The finding of a positive secular change in body stature has necessitated an update of growth charts (Appendix 2). Such charts are to be considered as tools to detect children with growth disorders and to evaluate growth promoting therapies, in youth health care as well as in pediatrics. Another consequence of the secular change was that the existing target height formula would have to be adapted (see paragraph 2 of this chapter).

We have not been able to study the phenomenon of secular change in children of Turkish and Moroccan origin in the Netherlands, because no data on immigrant children's heights were known until now (Chapter 7 and 8). However, we expect in next generations a trend to increasing heights, when immigrant children can share similar wealth, food, and health conditions as their Dutch contemporaries.

At present, compared to the Dutch population height differences were small for the Turkish during infancy, but increased to approximately -1.5 SD (or 10 cm) at 20 years of age. Their final height was 174.0 cm for boys, and 160.7 cm for girls. Height differences between Moroccan and Dutch children started slightly later, from 2 years onwards. Mean height difference increased from –0.2 SD to –1.3 SD (9.3 cm) for boys (174.7 cm) at 20 years of age and to –1.4 SD (9.6 cm) for girls (161.3 cm).

Although the environmental conditions might lead to a positive secular growth change in the next decades, it may in fact be smaller than expected. This is caused by the fact that family forming has continued to occur with partners from Turkey and Morocco, so that a third generation of Turkish and Moroccan immigrants in the Netherlands is still very small. Compared with Turkish studies, however, Turkish children in the Netherlands are taller than their age-mates living in rural Turkey where they come from, and have similar mean heights as the Turkish children in high SES groups in Istanbul.

Based on the present large differences in height between the ethnic Dutch children and the Turkish and Moroccan children, we have now chosen to construct separate growth charts for these ethnic groups. It is to be discussed whether this strategy should be repeated in future growth studies. It is expected that in the future more integration into Dutch culture and more mixed marriages will occur. Even if that would not be the case, the multiethnic nature of the present Dutch population might favour the alternative strategy, i.e. to construct one growth reference derived from a representative sample from the whole (multiethnic) population. The potential loss of discriminative power for the detection of growth disorders might be counterbalanced by a more intensive use of target height in the evaluation of growth. In that case, average final height of the Dutch population would become lower than the extrapolation of the previous 4 growth studies as discussed earlier in this paragraph. This would obviously also make it impossible to calculate secular trend directly from the average final height measurements.

3. Target height

An individual's height is strongly influenced by the genetic background. In a Swedish longitudinal study the correlation coefficient between final height of the child and the parental height in normal healthy children was 0.54 for men and 0.67 for women (6). This positive correlation has led to the introduction of the term 'target height', i.e. the final height that would be expected on the basis of parental height.

There are several formulas for calculating target height. The corrected midparental height method was introduced by Tanner in 1970 (7) and is still commonly used to estimate target height in children. Its general form is (paternal height + maternal height) + or - *a* cm) / 2 + *b*, where *a* = the difference between mean final male and female height, *b* = secular growth change. Tanner proposed to use: (paternal height + maternal height) + or - 13 cm] / 2, because in most growth studies the difference between male and female final height is 13 cm. This formula has the advantage of being simple and straightforward, but it was already indicated by Tanner that an additional correction for target height should be added.

Between 1980 and 1998 in the Netherlands the following corrected target height formula was used, based on the 1980 study: (paternal height + maternal height) ± 12) / 2 + 3, because the difference between mean final male and female height in the 1965 growth study was 12 cm, and the secular growth change was estimated at 3 cm.

When the final height data of the 1997 growth study became available, we felt that the formula should be adapted. For this purpose, we made 5 assumptions:

1. we assumed that the positive secular growth change would continue in the coming years, however at a slower rate;
2. we considered the time between generations to be 30 years, according to national statistics in 1997 that Dutch parents have their first child at a mean age of 28.9 years;
3. we proposed that a new adapted target height formula should be fit to use for the next 15 years until a possible fifth growth study will be performed;
4. we assumed that a relatively simple statistic formula without taking account of the statistic phenomenon of regression to the mean would be sufficient; and

5. finally, we postulated that the target height formula should be practical and easy for clinical use in diagnosing growth disorders.

As mentioned above, in 1985 it was decided to use a final height difference between sexes (*a*) of 12 cm, based on the 1965 growth study (11.7 cm). The correction for secular growth change was estimated at 3 cm (*b*), the mean difference between the 1965 and 1980 growth study. We now calculated the mean height difference between male and female final height over the 4 growth studies held in the Netherlands. While in the 1997 growth study the gender difference in final height was 13.4 cm, the mean difference over the four growth studies was 12.95 cm. In agreement with the original formula by Tanner, and taking into account the international literature, we now decided that 13 cm would fit best for *a*.

For changing *b* we assumed that the target height formula should be useful for young adults of 18-20 years in 1998, but also for 3 year old children in 2012. The generation difference between 18-20 year olds and their parents is 5.15 cm (1997-1965, assuming that parents are 30 years older than their offspring). Towards 2012, the data on secular growth change are available for the period 1980-1997 (2.15 cm) and for the next 15 years towards 2012 we estimated a secular change of 1.7 cm. This resulted in a generation difference of 3.85 cm in 2012. As in the time between 1997 and 2012, the mean generation difference would be close to 4.5 cm ([5.15+3.85]/2), we decided for *b*=4.5 years. This leads to the following formula: TH= (father's height + mother's height ± 13)/2 + 4.5, in short it means for boys TH= mean parental height +11 cm, and for girls TH= mean parental height –2 cm. The target range, defined as the area 1.3 SD below and above the target height was calculated as 1.3 times 7.1 = 9.2 cm for boys and 1.3 times 6.5= 8.5 cm for girls. For practical purposes this is rounded to 9 cm below and above the target height.

Further observational studies are necessary to validate the above calculated target height formula. In addition, one should note that little is known about the validity of this formula in case of extreme heights of one of the parents, as some growth disorders have a dominant pattern of inheritance. One should always be alert for the existence of a growth disorder in one of the parents themselves. Furthermore, in the clinic it is important to measure parental heights instead of just asking for it, as females overestimate their own heights and their partner's height (8).

Recently, an alternative target height formula was published (9) which corrects for assortative mating and the regression bias and is independent of sex. Its formula is: (*c*TH SDS= 0.72 times the average of father's and mother's height SDS). If parental height SDS is obtained from growth charts dating back one generation, the formula is also independent of secular height changes.

4. Secular changes in pubertal development

In the literature about secular trend, it is generally assumed that a positive secular change in body stature is accompanied by an advancement of pubertal development.

Interestingly, we have demonstrated that the positive secular change towards an earlier development of puberty between 1965 and 1980 has more or less stabilized thereafter in the Netherlands (chapter 4), and even a slight increase in some of the ages at attainment of pubertal stages can be observed. In some instances it appears that the interval between successive stages has tended to decrease. However, one should be cautious in such interpretation, as our data are derived from a cross-sectional study design and reliable information on pubertal progress can only be obtained from a longitudinal assessment.

There is some confusion about a possible change of the age at onset of genital development in boys. The median age at stage G2 in boys tended to increase between 1965-1997, but the median age at attaining a testicular volume of 4 ml decreased by 0.5 years to 11.5 years in 1997. Probably this confusion is caused by a difference in interpretation of the definition of G2 between the different studies. In Tanner's original definition of G2 there are two criteria: testicular enlargement and reddening of the scrotum. The use of two different criteria for the definition of one stage leaves room for confusion, because both phenomena can occur at different ages, and one criterion is less objective as the other. We propose that for future studies G2 should be defined as an enlargement of testicular volume. Which testicular volume should be taken best, is then still a matter of debate. In growth studies a testicular volume of 4 ml is commonly used as cut-off limit, but there is evidence that the biochemical changes associated with the onset of puberty correlate better with a testicular volume of 3 ml.

The P_{50} of the age at onset of puberty (B2 stage) in girls has decreased from 11.0 years in 1965 to 10.7 years in this study. Age of menarche decreased by about 0.5 years from 1955 till now, with in the period 1980-1997 only a small decrease of about 1.5 months from 13.28 to 13.15 years. In Denmark, Finland, France, and Greece a similar moderate decline in age at menarche is seen, while in United Kingdom, Sweden and Belgium a modest increase is seen, which provides evidence that the trend towards earlier menarche at least has come to arrest after a century (mid 19th-mid 20th century) in which the average menarcheal age decreased remarkably (10).

It is generally assumed that the increase in socio-economic conditions and general health is the main contributing factor for the trend towards earlier maturation, but the true mechanisms are unknown. A recent large review article urges further study of the onset of puberty as a possible sensitive and early marker of the interactions between environmental conditions and genetic susceptibility that can influence physiological and pathological processes (10).

On the physiological substrate for earlier pubertal development some hypotheses have been put forward, such as the so-called critical weight hypothesis, with leptin as a link between fat tissue and the central activation of the hypothalamus. Another hypothesis has postulated the influence of estrogen-like substances in the environment, for example phyto-estrogens present in soy-based feeding. The data we have presented suggest that not only age, but also weight, height, and BMI influence the chance of having menarche in the age range 11-15 years. Our data also indicate the presence of a specific weight, around 62 kg, and a particular BMI around 20 kg/m^2 where further increase in weight or BMI, respectively, does not influence a higher probability of having menarche at a given age. This is consistent with the finding that premenarcheal girls in all age ranges analyzed had a mean BMI < 20 kg/m^2 (chapter 4).

Our data could also be used to answer the question if the current definition (for girls 8 years, for boys 9 years) for precocious puberty had to change in the Netherlands. In the United States the guidelines for the evaluation of girls with precocious puberty were recently revised, because data were presented that the age at onset of puberty in the general population had advanced (11,12). Obviously, the definition of precocious puberty should be based on the occurrence of secondary sexual characteristics in the general population. Based on the 1997 data the age at the cut-off of 2 SD below the mean (close to P_3) for B2 is close to 8.2 years and for G2 9.8 years. For testicular volume of 4 ml we did not have sufficiently reliable data for determining the -2 SDS cut-off. Thus, the current cut-off age for precocious puberty, i.e. 8 years for girls and 9 years for boys, can be maintained.

With respect to the immigrant adolescents, we found that puberty in Moroccan adolescents started at a similar age as in the Dutch, but the duration of puberty maturation stages seemed shorter. For Turkish adolescents we found similar results. However, a cross-sectional design is not optimal for studying the longitudinal process of pubertal development.

The median age at menarche for Moroccan girls was 12.9 years, 3.5 months earlier than Dutch girls and even 6 months earlier than girls in Marrakesh, Morocco (expected 13.4 years in 1997). There are a few possible explanations for the almost identical age at menarche as the Dutch girls. First, a further improvement of socio-economic conditions and decreasing family sizes (3.3 children), next to 96% coverage by child health care, may play a role (13). Second, or on top of the previous factors, a relatively high prevalence of overweight may be responsible for the relatively low age at menarche in Moroccan girls living in the Netherlands.

In Turkish girls, a similar phenomenon is seen, but the age at menarche occurred almost 5 months earlier compared to Dutch girls, at 12.8 years. These data are in good agreement with Turkish girls in Istanbul, and Turkish girls in Bremen (14). Part of the difference in age at menarche compared to the Dutch girls may be associated with the observed higher BMI values for age. In future growth studies it is interesting to observe pubertal development in immigrant children, in order to see whether the advance in age of pubertal maturation will continue or will stabilize. Longitudinal data would be even more recommended to assess if the duration of the pubertal maturation stages are truly shorter than observed in Dutch girls. Parent *et al.* describe in a large review on this topic an overall early onset of puberty and increased incidences of sexual precocity in foreign children who migrate from developing countries to Western Europe, and probably also to the United States, what put emphasis on the role of environmental factors. However, a single explanation does not exist and further studies should evaluate the effect of migration by comparing the timing and dynamics of pubertal development in the developing and developed countries (10).

5. The rising prevalence of overweight

Compared to 1980, a striking increase in the mean and distribution of weight for height was seen in the population of the 1997 growth study (chapter 5). This in contrast to the period between 1965 and 1980, when hardly any difference was found. According to the international standard published by Cole *et al.* (15) we found in Dutch children a twofold increase in overweight since 1980, and obesity prevalence even tripled. The present Dutch overweight prevalence is similar to that in the United Kingdom (1994) (16) and may be expected to follow the trend in the USA if no accurate preventive campaigns and interventions will be made.

The increase in prevalence of overweight and obesity is seen in Dutch children particularly in urban areas, but prevalences are even higher in Turkish and Moroccan children, with for all children a peak between 4-7 years of age (chapter 6). Especially the peak in early childhood is alarming and indicates that overweight prevalence for older children may rise further in the coming years. Appropriate interventions are therefore urgently needed. Parent obesity is a known risk factor for becoming obese as a child and tracking into adulthood, so family and society orientated prevention strategies are important to avoid continuing increasing numbers of overweight adults in the future and to avoid large pressure on future health care caused by obesity related disorders. In 1999, health care costs directly related to overweight already were 505 million euro. Indirect costs (less productivity) are estimated at 2 billion euro/year (17). In Finland for example, for 9% of men and 22% of women is overweight the reason for not joining labour (18). This underlines the need for prevention strategies by the government with attention to people who are (still) of normal weight, in order to counterbalance the overweight stimulating environmental circumstances in society.

With regard to overweight, there is a clear sex difference, particularly in the Moroccan group. Girls have higher prevalences than boys. It is unclear whether the difference between Turkish and Moroccan children is due to genetic or to cultural factors, but both prevalences are comparable to the alarming US data. In our view national campaigns and programs are needed to stimulate regular physical activity in children, especially in urban areas, besides a more balanced and healthier food intake. Obesity is a problem and responsibility of society but also of individuals, families and not the least food industries. It is disturbing to see the prediction of the future prevalence of overweight in the coming years. Prevention programs in cooperation with food and sport industries may be important tools. An example is the program Mission Olympic, financed by Coca Cola and performed by NOC*NSF, that stimulates and facilitates children to join sportclubs, and stimulates physical activities for children at schools and after school (C.J. van den Bemt, NOC*NSF, unpublished). Specific attention is needed for programs targeted at immigrant children as cultural background and perception of overweight and obesity are different.

6. The clinical use of the growth charts

Based on the 1997 growth study, we published growth charts for length, height, sitting height, leg length, sitting height/height, body mass index, waist circumference, hip circumference, and waist hip ratio for age and weight for height. These are all shown in Appendix 2, and further explained in a separate brochure (19). The format of the 1997 growth charts was determined by an ad hoc working group 'lay –out growth charts 1997', consisting of representatives of youth health care, pediatricians, pediatric endocrinologists, dieticians, statisticians, epidemiologists and lay-out specialists.

The working group had to make several decisions. In comparison to the 1980 growth charts, the most pronounced difference was the change to SD reference lines like the British and WHO charts instead of centiles (20). This decision was taken after carefully comparing the pros and cons. For example, centiles charts have the advantages that parents can easily understand the position of their child on the charts, and health workers were used to work with centiles. On the other hand, there are several disadvantages of centile charts, which finally tipped the balance in favour of SD reference lines. One of the reasons was that it is easier to express measurements far below P_3 as SDS than as a centile. Another reason was that in the centile chart the distances between centiles differ from each other (i.e. the distance in cm between P_{10} and P_{20} is more than that between P_{20} and P_{30}), while the distance between 0 and -1 SDS is equal to the distance between -1 and -2, etc. Finally, centiles cannot be used to compare growth between subpopulations or between different international populations, as they are unsuitable for statistical purposes.

The second decision referred to the distance between SD lines. All charts (except weight for height) have 7 SD lines: 5 SD lines indicating the "normal area" at 0 SDS (P_{50}), -1 SDS (P_{16}), -2 SDS (P_2), + 1 SDS (P_{84}) and + 2 SDS (P_{98}) and 2 lines for -2.5 SDS ($P_{0.6}$) and + 2.5 SDS ($P_{99.4}$). In the original charts, for weight for height 0 SDS, -2 SDS and + 2 SDS were noted. However, we have recently decided that in order to early recognize children at risk for overweight or underweight, a +1 SD line and a -1 SD line should be added for timely prevention and therapeutic interventions.
Thirdly, it was decided that separate growth charts for Turkish and Moroccans in the Netherlands were useful, because of the high percentage of Turkish and Moroccan children that would be diagnosed abnormally short on Dutch standards. About 10% of the prepubertal Turkish and Moroccan children were below the Dutch –2 SD lines, of whom the majority should still be labeled as growing normally according to their own growth chart.

Also for weight for height and BMI we found differences between the ethnic groups but in contrast to height, separate growth charts were thought not to be necessary. BMI reference data describe the distribution of weight in the population and are in fact not normative but descriptive tools. This in contrast to height reference data which are necessary to distinguish growth disorders. Being fat is not the norm for a population and shifting upwards of the reference lines would never detect the children at risk for overweight and obesity and related disorders. Therefore we chose to include the international standard (IOTF) for BMI in the Dutch BMI charts. This standard is based on 6 international studies, among them the 1980 Dutch growth study. All studies were performed in times that obesity was not yet such a common problem as nowadays. This means that in future growth studies height, sitting height, and head circumference measurements are necessary for updated growth reference norms, but weight and BMI measurements are necessary for follow-up of the prevalences of under- and overweight and obesity in the population during a period, compared to a fixed reference in time, i.e. the international standard.

New in this 1997 study were three biometric measurements: sitting height (a parameter of body proportions), waist circumference, and hip circumference. In the differential diagnosis of growth disorders it is important to judge whether growth is proportionate or disproportionate (chapter 3). For this purpose, up-to-date age references for height (H), sitting height (SH), leg length (LL) and SH/height (SH/H) are useful. The SH/H ratio varied from 0.68 infancy to 0.52 in adolescence, indicating that in the prepubertal years growth occurred mainly by growth in the limbs, more than in the trunk. This is also shown by the decreasing sitting height / leg length ratio from 2.10 to 1.08 at 10 years of age. Thus, growing taller is mainly due to increasing leg length.

We found a low, but statistically significant, negative correlation between SH/H and height. Thus, tall children have relatively long legs and short children relatively short legs. For a proper interpretation of SH/H ratio the cut-off limits for normality should therefore be corrected for body stature. We found that in short children a cut-off of 2.5 SDS is better than a cut-off of 2 SDS. In tall children an SH/H ratio of about -2.2 SDS would be a better cut-off limit for normality. However, instead of using fixed cut-off limits, one can better plot individual observations on the diagram of SH/H SDS versus H SDS.

We tried to evaluate the sensitivity of these body proportions +/- 2 SD cut-off lines for detecting hypochondroplasia and Marfan syndrome by comparing body proportions of these two patient groups to the reference population. We found that these body proportions cut-off lines were useful to detect i.e hypochondroplasia, but cannot be used to exclude these growth disorders. We observed that in the family with mild hypochondroplasia, height is not extremely aberrant but the sitting height /height ratio is ≥2.5 SDS. For hypochondroplasia and Marfan patient groups, we found that the ellipse method is a better criterion to detect growth disorders than the +/- 2 SD cut-off lines method. Further investigations on larger groups of patients are necessary to further validate the clinical usefulness of this method aimed at providing an objective basis for recognizing disproportionate growth. For future studies it is also recommended to study the inter-observer variation for sitting height measurements, as errors in SH measurement are easily made, which can lead to considerable inter-observer variation. We did not measure leg length itself, but leg length was obtained by subtracting sitting height from height.

Other new growth charts present reference lines for waist circumference (WC), hip circumference (HC) and waist/hip ratio for age (chapter 6). WC has some advantages above BMI: it is relatively easy to perform and instruct, also to subjects themselves; it has a low intra-and inter-observer variation; and it is associated to BMI, fat distribution and metabolic abnormalities with a good predictive value to risks for overweight in the future. It has been shown that a greater deposition of central fat increases the risk of metabolic complications in obese children, so early identification and treatment of children with high central adiposity is important (21). However, longitudinal studies on the association between adult disease and WC in childhood are still lacking.

In a few other countries WC reference charts for children were constructed. However, there is no consensus about the best cut-off in children. Despite the more general use in adults and some cut-off suggestions (22,23), there is neither consensus about the best cut-off in adults. It is known that tracking of obesity to adulthood is greater in children with high WC, so WC can be an useful diagnostic tool for recognizing overweight and obesity. We suggest to take the 1.3 SDS for overweight and 2.3 SDS for obesity in children, according to the percentage children detected by the BMI cut-off line based on the IOTF standard. This would mean that at present 10% of the children would be labeled as having an enlarged waist circumference. In future studies it is recommended to validate these cut-off points. In order to study which WC cut-off is useful for identifying children at risk, prospective studies are needed to produce data on later metabolic abnormalities and high fat mass in adulthood.

7. Implications for society and future research

It is an open question whether the 1997 growth study should be followed approximately 15 years later by a fifth Dutch growth study with a similar design as the previous four studies. During the years, new methods have been introduced that are possibly less expensive, because less children and less health workers would have to be included. In the first three growth studies, hand-written data were collected through questionnaires, followed by manual data processing and manual production of growth curves. In the 1997 study, methods and efficiency had improved so that smaller numbers of children (n=14,500 compared to n=42,000 in 1980) were measured, data management was processed by computers, and growth curves were produced with existing statistic computer programs and computer modelling. In the coming years however, web technology will have been further improved, rendering written questionnaires and the complicated logistic organization redundant. For example, one could think of a system of continuing data collection by using internet facilities. Along the same lines, the traditional nationally organized growth monitoring studies may be replaced by a system of European growth monitoring which continuously collects data. This has the advantage that also longitudinal data will be available and more information will be obtained about growth velocity and duration of pubertal stages.

An alternative method might be the method developed by Hermanussen, which is certainly useful for third world countries. Based on growth data of more than six hundred growth studies, the model predicts the growth curve when mean heights at only three or four ages were given. This makes it possible to diminish measurement moments and to include less subjects. A first comparison of this model with the 1997 growth curves showed only small differences (Fredriks *et al.*, unpublished), but further study is needed.

The impact of the study results for society have been large in various fields. National and international media attention was paid to the continuing positive secular growth and the increasing prevalence of children with overweight. The club of tall people used the data for letters to government and industries for ergonomic adaptations (www.klublangemensen.nl). The Ministry of Health, Welfare and Sports discussed a note on the alarming overweight rates in children in the Netherlands and follow-up studies and study proposals for the development of follow-up and prevention strategies or treatment programs were developed. In youth health care and pediatrics, more attention is paid to the use of body mass index, waist circumference, and body disproportions in diagnostic procedures, although further implementation programs are necessary.

Concrete study proposals that directly followed the 1997 growth study were a recently finished project on the diagnostic value of height SDS, target height corrected height SDS, and height SDS change for the diagnosis of Turner syndrome (24), a project application for a similar project on growth hormone deficiency, a current project for developing new guidelines for growth monitoring and assessing failure to thrive (25), project applications for assessing the diagnostic value of head circumference, and proposals for early interventions for overweight children.

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Chapter 12

Summary

Summary

Since 1858 a striking increase of mean stature and an earlier sexual maturation, usually called positive secular growth change, has been observed in the Netherlands, interrupted by relatively short periods of a diminished height gain or even height loss during agricultural crises, the world economic crisis in 1930, and World War I and II. It is generally assumed that this secular change is elicited by a change of environmental conditions and reflects improvements in the nutritional, hygienic, and health status of a population. Growth of a population can therefore be used as a 'mirror of conditions in society'. Before 1955, growth data were mainly estimated from data on conscripts and other, non-random samples from the population. However, in 1955, 1965, and 1980, three large cross-sectional nation-wide growth studies were performed. This thesis presents the fourth nation-wide growth study, performed in 1996-1997.

In **Chapter 1** a general introduction is given on secular growth change in the Netherlands, and on the main purposes of growth studies and growth references. This chapter describes the study design of the 1997 Dutch growth study. We used a methodology similar to the previous growth studies, to compare the results and to assess whether any further secular change has occurred. New in this 1997 study were three biometric measurements: sitting height (a parameter of body proportions), waist circumference, and hip circumference. Besides, growth reference data for children of Turkish and Moroccan origin, living in the Netherlands, were presented.

In **Chapter 2** the secular change over the four growth studies was studied for children of Dutch origin. A positive secular growth change has been present during the past 42 years (1955-1997) for children, adolescents, and young adults of Dutch origin, although at a slower rate between 1980 and 1997 (1.3 cm/decade). The average final height for boys was 184.0 cm, for girls 170.6 cm. However, in infancy, no secular shift of length was found. Height differences according to region, educational level of child and parents, and family size have remained over the past years. With regard to puberty, for girls the median age at menarche has continued to decrease at a slow rate (by 6 months) during the past four decades, and was in 1997 13.15 years. The onset of sexual maturation in both sexes occurred slightly later than in 1980. From the positive secular change, one can conclude that environmental conditions have been favourable for many decades in the Netherlands. Improved nutrition, child health, hygiene, and a reduction of family size are conditions that might be responsible for the continuing positive secular growth change.

In **Chapter 3** we present growth charts for sitting height (SH) (crown-rump length for infants), leg length (LL) and sitting height/height (SH/H) ratio for children of Dutch origin, aged 0-21 years. We found a positive association between height SDS and sitting height SDS and leg length SDS in all age groups. A low but statistically significant negative correlation was found between SH/H SDS and H SDS. To detect disproportionate growth, an acceptable cut-off limit with a small number of false positive results is needed. For practical purposes, for short children (height < -2 SDS), a cut-off limit for SH/H of +2.5 SD is suggested. In exceptionally tall children (height >2 SDS), a cut-off limit for SH/H of -2.2 SDS can be used. Alternatively, a nomogram of SH/H SDS versus H SDS is a useful tool in the work-up of children with growth disorders and provides an objective basis for recognizing disproportionate growth. The proposed cut-off lines were studied on two small groups of patients. The sensitivity of the height-corrected cut-off lines for hypochondroplasia was fair (80%), for Marfan syndrome these cut-off lines were less useful (30%).

Chapter 4 describes more detailed the sexual maturation. In the Netherlands, the age at onset of puberty or menarche has stabilized since 1980. The age at menarche is not only dependent on age, but also on height, weight, and BMI. At a given age, tall or heavy girls have a higher probability to have menarche compared to short or thin girls. However, a body weight exceeding 60 kg (+1 SDS) or a BMI of > 20 kg/m^2 (+1 SDS) does not further increase the chance to have menarche, while for height such a ceiling effect was not observed. Thus, for heavy girls, beyond a weight or BMI of +1.0 SDS, this dependency disappears, but with increasing height, chances on having menarche at a certain age still increase. For girls, the start of puberty, measured as the 50th percentile of Tanner breast stage 2 (B2), was 10.7 years. For boys, this was at 11.5 years of age, when 50% of the boys had reached a testicular volume of 4 ml. The observed increase of the age at genital stage 2 (G2) in 1997 compared to 1965, is probably due to different interpretations of its definition. The definition of precocious puberty was studied in our data and it was not found necessary to change the definition. The age limits for the definition of precocious puberty that are currently in use (9 years for boys, 8 years for girls), are close to the 3rd percentile of the previous and the 1997 reference data. Finally, a high agreement was found between the pubic hair stages and stages of pubertal (genital and breast) development, but slightly more in boys than in girls.

In **Chapter 5** BMI-age reference charts were constructed for children of Dutch origin in the age range 0-21 years. Compared to 1980, BMI age-references have increased, especially in childhood and adolescence. For comparison, we used the 90th, 50th, and

10th BMI centile of 1980. From 3 years of age onwards, 14-22% of the children exceeded the P_{90} of 1980, 52-60% the P_{50}, and 92-95% the P_{10}. For all ages, the -0.9 SD, +1.1 SD, and +2.3 SD lines in 1996-1997 corresponded to the adult cut-off limits of 20 kg/m^2, 25 kg/m^2, and 30 kg/m^2, also recommended for children by the WHO/ECOG. The prevalence of overweight and obesity was higher in girls than in boys. Taking a BMI of 25 kg/m^2 as the limit, on average 13.4% of young adults were overweight. This corresponded approximately to the paediatric +1.1 SD line in the 1997 reference charts. For identifying underweight, a BMI value of 20 kg/m^2 would result in categorizing more than 20% of children as underweight. The adult BMI cut-off of 18.5 kg/m^2 might be more useful in the Netherlands; this would correspond to the paediatric –1.8 SD line, and consequently 4% of children would be categorized as underweight. BMI was related to region, educational level of parents and family size. Children in large cities, and children with poorly educated parents showed a relatively high BMI SDS. We concluded that the observed rise in childhood obesity will result in increased adult obesity and obesity related disorders in the near future, therefore prevention programs are urgent in youth health care.

Chapter 6 presents national waist circumference (WC), hip circumference (HC) and waist/hip ratio (WHR) reference charts for 0-21 year old boys and girls. WC has some advantages above BMI: it is relatively easy to perform and instruct, also to subjects themselves; it has a low intra-and inter-observer variation; and it is associated to BMI, fat distribution and metabolic abnormalities with a good predictive value to risks for overweight in the future. Mean WC and HC values increased with age. Mean WC was slightly higher in boys than in girls, and this difference was statistically significant from 11 years of age onwards. In contrast, HC was significantly higher in girls than in boys from 9 years onwards. The correlation between WC SDS and BMI SDS (r=0.73, p<0.01) and between HC and BMI SDS (r=0.67, p<0.01) increased with age. With regard to WHR SDS, a low correlation was found for adolescents ≥12.5 years of age (r=0.2, p<0.01). WC SDS correlated positively with height SDS (r=0.35, p<0.01). Waist circumferences can be used to screen for increased abdominal fat mass in children, however, a suitable cut-off point does not exist. For the establishment of long term health effects of increased abdominal fat mass in childhood longitudinal data are necessary. Until these studies will be available, we suggest to calculate cut-off points according to the IOTF standard for BMI. In our data, a cut-off limit of 1.3 SDS appears most suitable to assess overweight in children.

In **Chapter 7** reference charts for children (0-20 years of age) of Turkish origin in the Netherlands are presented. Young Turkish adults were 10 cm shorter than their Dutch contemporaries. Mean height was 174.0 cm for males, 160.7 cm for females. Height differences in comparison with Dutch children started from 3 years onwards. The height of Turkish children living in the Netherlands was similar to Turkish children in Germany and to children from high socio-economic classes in Istanbul. Compared to Dutch children, maturation stages started 0.5-0.7 years later for both sexes, but the progression through puberty seemed faster. However, one should be aware that our data are derived from a cross-sectional study instead of longitudinal data, so that progression cannot reliably be assessed. In girls, median age at menarche was 12.8 years, 5 months earlier than in Dutch girls. The association between height and background variables showed that height SDS was predominantly associated with target height. Compared to the Dutch BMI reference charts, the BMI of Turkish children were higher than that of Dutch children at all ages, for both sexes. BMI SDS was associated with birthweight and the duration of maternal residence in the Netherlands. According to the height differences, separate growth charts for Turkish children in the Netherlands are useful for growth monitoring at this moment, as Turkish children are considerably shorter. By using Dutch charts, a substantial part of immigrant children would be considered abnormally short for age, while they are normal compared to their own specific growth chart.

In **Chapter 8** separate growth charts for children (0-20 years of age) of Moroccan origin in the Netherlands are presented. Comparisons between Dutch and Moroccan growth data illustrated that Moroccan young adults were on average 9 cm shorter than their Dutch contemporaries. Mean final height was 174.7 cm for males, 161.3 cm for females. Height differences in comparison with Dutch children started from 2 years onwards. Compared to Dutch children, maturation stages started 0.2-0.9 years later for girls and boys, respectively, but the progression through puberty seemed faster. However, as mentioned above, cross-sectional data are of limited value for the interpretation of progression. In girls median age at menarche was 12.9 years, 3.6 months earlier than in Dutch girls. The correlation between height SDS and BMI SDS and background variables was calculated. Height SDS was predominantly associated with target height. BMI SDS was only associated with birthweight in children <5 years of age. Compared to the Dutch BMI reference charts, the BMI of Moroccan children was slightly above that of Dutch children, especially for girls. We concluded that similarly to children of Turkish origin, separate growth charts for Moroccan children in the Netherlands are useful for growth monitoring, as Moroccan children are considerably shorter.

Chapter 9 illustrates the seriousness of overweight in children in the Netherlands for the three ethnic groups according to the criteria suggested by IOTF (2001). This standard is based on BMI reference data from 6 international studies, dated before the 'epidemic of obesity', and included the Dutch 1980 study. The percentages of Turkish, Moroccan, and Dutch children aged 2-20 years exceeding the IOTF age- and sex specific cut-off points were described, for both overweight and obesity. Average overweight (obesity) prevalences across age for Turkish boys and girls were 23.4% and 30.2% (5.2% and 7.2%), for Moroccans 15.8% and 24.5% (3.1% and 5.4%), for Dutch in the large cities 12.6% and 16.5% (1.6% and 2.8%), and for the remaining Dutch children 8.7% and 11.3% (0.8% and 1.4%). For all groups of children living in the large cities, we found significant associations between overweight and ethnicity, parental education (-), and gender (+girls). The effect of parental education disappeared when the relation between education and overweight was corrected for ethnicity and gender. It is disturbing that Turkish and Moroccan (girls) prevalences for overweight are comparable to the alarming US data. Therefore culturally embedded prevention strategies are needed for all children living in urban areas and even more so in Turkish and Moroccan children, to avoid large pressure on future health care caused by obesity related disorders.

Chapter 10 describes more detailed the method used for the construction of the reference curves in the 1997 Growth Study. We used the LMS model of Cole and Green to construct reference curves. If the model fitted, the measurements in the reference sample followed a standard normal distribution at all ages after a suitably chosen Box-Cox transformation. The coefficients of this transformation are modelled as smooth age-dependent parameter curves for the skewness (L), median (M), and coefficient of variation (S), respectively. The fit of each parameter curve is closely related to particular features in the worm plot, i.e. its offset, slope and curvature. The major modelling task was to choose the appropriate amount of smoothness of each parameter curve. We think that the wormplot can contribute to this process. The worm plot assesses the age-conditional normality of the transformed data under a variety of LMS models. The worm plot is a general diagnostic tool for the analysis of residuals and visualizes differences between two distributions, conditional on the values of a covariate. In this chapter, the covariate of interest is age. The used procedure resulted in satisfactory reference curves for a variety of anthropometric measures and it can be concluded that the wormplot could improve the transparency of the LMS method.

In **Chapter 11** several themes from the foregoing chapters are discussed, in which the data of Dutch, Turkish, and Moroccan children are included; the study design, the secular height change, target height and the considerations for an updated formula, the secular changes in pubertal development, the consequences of the rising obesity prevalence in the Netherlands, the choices that are made for an optimal design of the growth charts, the clinical use of these growth charts, the implications of the 1997 Dutch Growth Survey for society, and finally, recommendations for future studies are made.

Chapter 12

Chapter 13

Samenvatting

Samenvatting

Sinds 1858 is de gemiddelde lengte van Nederlanders toegenomen. Deze toename is gedurende korte perioden onderbroken geweest; tijdens de Eerste en Tweede Wereld oorlog en tijdens economische en/of agrarische crises. Een toename van de gemiddelde lengte (of wel een positieve seculaire lengte verschuiving) wordt wel gebruikt als weerspiegeling van een verbeterde gezondheid, voedingsstatus en hygiëne van de bevolking. Tot 1955 berustten groeidata op meetgegevens van dienstplichtigen en andere kleine cohorten. Echter in 1955, 1965 en 1980 zijn in Nederland drie grote landelijke groeistudies uitgevoerd. Het hier beschreven onderzoek is het vierde landelijke groeionderzoek, uitgevoerd in 1996-1997.

In **Hoofdstuk 1** wordt de seculaire groeiverschuiving in Nederland besproken en wordt het doel van groeistudies en groeireferentiewaarden toegelicht. Daarnaast wordt de studie opzet van de vierde landelijke groeistudie beschreven. De studie opzet van 1980 werd als uitgangspunt genomen om vergelijkbare resultaten en inzicht in de seculaire groeiverschuiving te verkrijgen. Nieuw in de 1997 studie zijn: 3 extra biometrische variabelen; zithoogte (als maat voor lichaamsverhoudingen), taille-omtrek en heup-omtrek. Ook zijn groeigegevens verzameld van kinderen van Turkse en Marokkaanse afkomst die in Nederland woonachtig zijn.

In **Hoofdstuk 2** worden de 1997 groeidiagrammen voor lengte, gewicht, gewicht naar lengte en hoofdomtrek voor 0-21 jarigen van Nederlandse afkomst gepresenteerd. Het hoofdstuk beschrijft gedurende de gehele 42 jarige periode (1955-1997) een positieve seculaire groeiverschuiving voor zowel kinderen, adolescenten als jong volwassenen, hoewel de toename tussen 1980 en 1997 minder uitgesproken was (1.3 cm/decennium). De gemiddelde eindlengte voor jongens was in 1997 184,0 cm, voor meisjes was dit 170,6 cm. Opvallend was dat bij zuigelingen, tot de leeftijd van 1 jaar, geen seculaire verschuiving voor lengte werd gevonden. Wat betreft de correlatie tussen lengte en achtergrondgegevens, bleven verschillen naar regio (noorden langer dan zuiden), opleidingsniveau van ouder en kind (hoger opgeleid langer) en gezinsgrootte (kleinere gezinnen langer) ook in de 1997 groeistudie bestaan. Bij vergelijking van de puberteitsstadia was de mediane leeftijd voor menarche (eerste menstruatie) voor meisjes in de afgelopen 4 decennia 6 maanden vervroegd. In 1997 was de mediane menarche leeftijd 13.15 jaar. Het begin van de puberteit leek echter iets later te beginnen dan in 1980. Al met al lijkt het erop dat de gunstige sociaal economische condities hebben geleid tot een verdere toename van de lichaamslengte, maar dat de toename in eindlengte geringer is dan tevoren. De maximale eindlengte lijkt nog niet te zijn bereikt. Mogelijke verklarende factoren voor de toenemende lengte zijn: een verbeterde voedingskwaliteit, hygiëne en gezondheid van de jeugd en een kleinere gezinsomvang.

Hoofdstuk 3 omvat de groeidiagrammen voor zithoogte (ZH) (of wel romplengte voor zuigelingen), beenlengte (BL) en zithoogte/lengte ratio (ZH/L) voor Nederlandse 0-21 jarigen. Deze diagrammen voor lichaamsverhoudingen zijn in de 1997 groeistudie voor het eerst uitgegeven. Het hoofdstuk beschrijft positieve correlaties tussen de lengte (L) standaard deviatie score (SDS) en de ZH SDS en BL SDS voor alle leeftijden. Tussen L SDS en ZH/L SDS werd een lage, maar statistisch significante negatieve correlatie gevonden. Om disproportionele groeistoornissen op te sporen is een afkappunt voor ZH/L gewenst met weinig vals positieve bevindingen. Op basis hiervan stelden wij voor om bij kleine kinderen (lengte <-2 SDS), een afkappunt voor ZH/L ratio >2.5 SD als afwijkend aan te houden. Voor extreem lange kinderen (lengte >2.0 SD) adviseerden wij een afkappunt van –2.2 SDS. Als alternatief hulpmiddel bij het opsporen van disproportionele groeistoornissen kan ook een nomogram voor ZH/L SDS afgezet tegen L SDS worden gebruikt. Wij bestudeerden de voorgestelde afkappunten op 2 kleine groepen patiënten met hypochondroplasie en het Marfan syndroom. De sensitiviteit van de voor lengte gecorrigeerde afklaplijnen was bij patiënten met hypochondroplasie vrij hoog (80%), voor kinderen met Marfan syndroom was dit beduidend lager (30%).

In **Hoofdstuk 4** wordt nader ingegaan op de puberteit. Het begin van de puberteit en het moment van menarche is weinig veranderd in vergelijking met 1980. Uit onze data blijkt dat de menarche niet alleen afhankelijk is van de leeftijd maar ook van lengte, gewicht en body mass index (BMI). Op een bepaalde leeftijd hebben lange of zware meisjes een grotere kans op menarche dan kleine of magere meisjes. Deze grotere kans op menarche vervalt als meisjes zwaarder zijn dan 60 kg (> +1 SDS) of een BMI groter dan 20 kg/m^2 (> +1 SDS) hebben. Voor lengte bestaat een dergelijk plafond niet. Hoe langer het meisje is, hoe groter de kans op menarche op een bepaalde leeftijd. Bij meisjes begon de puberteit (gemeten aan het eerste stadium van borstontwikkeling, B2) gemiddeld op een leeftijd van 10.7 jaar. Bij jongens bereikte 50% een testis volume van 4 ml op 11.5 jaar. Opvallend was dat het genitaal stadium 2 (G2) in 1997 later bereikt werd dan in 1965. Een mogelijke verklaring hiervoor is het gebruik van een verschillende definitie voor G2. De vraag of de definitie voor pubertas precox op basis van de 1997 referentie data aangepast moest worden werd bestudeerd. De huidige leeftijdsgrens voor pubertas precox is voor jongens 9 jaar, voor meisjes 8 jaar. In de 1997 referentiewaarden liggen deze leeftijden ongeveer bij de derde percentiel, zodat de definitie onveranderd kan blijven in Nederland. Uit de data blijkt daarnaast een hoge correlatie (jongens>meisjes) tussen het bereiken van de stadia voor pubes beharing en de stadia voor genitaal ontwikkeling bij jongens en de borst ontwikkeling bij meisjes.

In **Hoofdstuk 5** is gekeken naar de verschillen in BMI tussen 1997 en 1980 voor 0-20 jarigen van Nederlandse afkomst. Als eerste werden BMI-leeftijd referentie diagrammen geconstrueerd. De BMI-leeftijd referentie lijnen bleken in de tussenliggende 17 jaar (1980-1997) omhoog verschoven. Voor de vergelijkingen werden de P_{90}, P_{50} en P_{10} BMI referentie lijnen uit 1980 als uitgangswaarden gebruikt. Vanaf het 3de leeftijdsjaar passeerden 14-22% van de kinderen de P_{90} van 1980, 52-60% de P_{50} en 92-95% de P_{10}. De –0.9 SD, +1.1 SD en +2.3 SD lijnen in 1997 kwamen overeen met de bij volwassenen gebruikte afkappunten 20 kg/m^2, 25 kg/m^2 en 30 kg/m^2. De WHO en ECOG suggereerden deze criteria ook voor kinderen te gebruiken. De prevalentie van zowel overgewicht als obesitas was bij meisjes hoger dan bij jongens. Voor jong volwassenen betekent dit dat gemiddeld 13.4% overgewicht heeft bij gebruik van BMI 25 kg/m^2 als criterium. Dit komt eveneens overeen met de +1.1 SD referentie lijn op de 1997 BMI diagrammen voor 0-21 jarigen. Voor ondergewicht is de –0.9 SD lijn, passend bij 20 kg/m^2, minder geschikt in Nederland. Dit zou betekenen dat 20% van de kinderen 'ondergewicht' zou hebben. De volwassen BMI afkapwaarde van 18.5 kg/m^2 is mogelijk geschikter, omdat deze overeenkomt met de -1.8 SD lijn in het BMI referentie diagram. Nu worden 4% van de kinderen met 'ondergewicht' gecategoriseerd. Opvallend was dat kinderen uit de grote steden, met laag opgeleide ouders, in één-ouder gezinnen of in twee-ouder gezinnen waarbij beide ouders buitenshuis werken, een significant hogere gemiddelde BMI SDS hadden. Als gevolg van de toename van het aantal kinderen met overgewicht is in de komende decennia een stijgend aantal volwassenen met overgewicht en obesitas te verwachten. Hierdoor is individu gerichte preventie door met name jeugdgezondheid medewerkers een urgente activiteit geworden.

Nieuw in de 1997 groeistudie zijn de diagrammen voor omtrekmaten, te weten taille-omtrek (TO), heup-omtrek (HO) en de taille/heup ratio (THR) naar leeftijd voor 0-21 jarigen. In **Hoofdstuk 6** worden deze diagrammen beschreven. De gemiddelde TO en HO waarden nemen toe met de leeftijd. De gemiddelde TO was bij jongens gemiddeld hoger dan bij meisjes. Vanaf het 11de jaar was dit verschil significant aanwezig. Daarentegen was de HO juist voor meisjes significant hoger dan voor jongens vanaf het 9de leeftijdsjaar. De correlaties tussen TO SDS en BMI SDS (r= 0.73, p<0.01) en tussen HO en BMI SDS (r=0.67, p<0.01) werden berekend. De correlaties werden hoger naarmate de leeftijd toenam. Voor THR was de correlatie met BMI SDS laag en alleen significant in de leeftijdsgroep ≥ 12.5 jaar (r=0.2, p<0.01). Alleen de TO SDS was positief gecorreleerd met de lengte SDS (*r*=0.35, *p*<0.01). TO is een goede maat voor het bepalen van het abdominale vet bij kinderen, het is goedkoop en gemakkelijk te meten, ook door de kinderen zelf. Echter, net als bij volwassenen bestaat er nog geen consensus over een afkappunt waarop de hoeveelheid abdominaal vet schadelijk is voor de gezondheid of een voorspeller is voor latere cardiovasculaire of andere aan vetzucht gerelateerde gezondheidsgevolgen. Longitudinale data zijn nodig om hier gefundeerde uitspraken over te doen. Zolang deze onderzoeken nog niet beschikbaar zijn stellen wij voor de IOTF criteria voor BMI te gebruiken, gezien de goede correlatie tussen TO en BMI SDS. In onze data voldoet een afkappunt > 1.3 SD als meest geschikt om overgewicht bij kinderen op te sporen.

Een ander verschil met de voorgaande groeistudies is dat in de 1997 groeistudie afzonderlijke groeidiagrammen zijn gemaakt voor 0-20 jarigen van Turkse afkomst, woonachtig in de vier grote steden in Nederland. In **Hoofdstuk 7** worden deze groeidiagrammen beschreven. 20-jarige Turkse jongeren zijn gemiddeld 10 cm korter dan hun leeftijdsgenoten van Nederlands afkomst. De gemiddelde eindlengte voor Turkse jongens was 174.0 cm, voor meisjes 160.7 cm. De lengteverschillen tussen Turkse en Nederlandse kinderen beginnen vanaf het derde leeftijdsjaar. De gemiddelde lengte van de Turkse kinderen in Nederland is ongeveer vergelijkbaar met de lengte van Turkse kinderen in Duitsland en de kinderen uit de hogere sociaal-economische klasse in Istanbul. Bij vergelijking van de puberteit ontwikkelingsstadia blijkt dat de stadia gemiddeld 0.5-0.7 jaar later startten bij zowel Turkse jongens als meisjes in vergelijking met de Nederlandse adolescenten. Hierbij viel op dat Turkse adolescenten de verschillende puberteitsstadia sneller leken te doorlopen. Waarbij in aanmerking moet worden genomen dat deze conclusie is gebaseerd op transversale data, terwijl longitudinale data hiervoor geschikter zijn. Turkse meisjes hadden hun menarche gemiddeld op 12.8 jaar, dit is gemiddeld 5 maanden vroeger dan Nederlandse meisjes. De Turkse BMI referentielijnen voor zowel jongens als meisjes lagen voor alle leeftijden hoger dan de Nederlandse BMI lijnen. De correlatie tussen lengte en achtergrondvariabelen was enkel voor target height significant. BMI SDS was gecorreleerd met geboortegewicht (+) en de verblijfsduur van de moeder (+) in Nederland. Op basis van de gevonden verschillen was de conclusie dat aparte diagrammen voor kinderen van Turkse afkomst op dit moment zinvol zijn voor het opsporen van afwijkende groei, aangezien Turkse kinderen opvallend korter zijn. Wanneer de groei van Turkse kinderen op de Nederlandse diagrammen gevolgd wordt, zou een aanzienlijk deel van de immigranten kinderen als abnormaal klein voor de leeftijd worden gediagnosticeerd en onnodig voor nader onderzoek worden verwezen.

In **Hoofdstuk 8** zijn op soortgelijke wijze de resultaten beschreven voor 0-20 jarige kinderen van Marokkaanse afkomst, woonachtig in een van de vier grote steden in Nederland. Dit resulteerde in groeidiagrammen voor lengte en BMI naar leeftijd. Een vergelijking tussen de Marokkaanse en Nederlandse referenties liet zien dat de gemiddelde eindlengte voor Marokkaanse jong volwassenen gemiddeld 9 cm kleiner was dan voor hun Nederlandse leeftijdsgenoten. De gemiddelde eindlengte voor jongens was 174.7 cm, voor meisjes 161.3 cm. De lengte verschillen begonnen reeds vanaf 2 jarige leeftijd. Wat betreft de ontwikkeling van de secundaire geslachtskenmerken, begonnen deze gemiddeld 0.2-0.9 jaar later voor meisjes, respectievelijk jongens, in vergelijking met kinderen van Nederlandse afkomst. Net als bij Turkse adolescenten, leken Marokkaanse jongens en meisjes de verschillende stadia sneller te doorlopen dan de Nederlanders, met de opmerking hierbij dat deze observatie was gebaseerd op transversale data. Marokkaanse meisjes hadden hun menarche gemiddeld op 12.9 jarige leeftijd, 3.6 maanden vroeger dan Nederlandse meisjes. De BMI referentielijnen lagen, vooral bij de meisjes, iets boven de Nederlandse BMI SD lijnen. Berekeningen van de correlatie voor lengte SDS en BMI SDS met verschillende achtergrondvariabelen, resulteerden in target height als een predisponerende factor voor lengte. Voor BMI SDS was enkel geboortegewicht een predisponerende factor bij de 0-5 jarigen. Uit deze resultaten volgde dat net als bij de Turkse kinderen, aparte groeidiagrammen voor lengte nuttig zijn om op adequate wijze afwijkende groei op te sporen, aangezien Marokkaanse kinderen significant kleiner zijn dan Nederlandse kinderen.

In **Hoofdstuk 9** worden specifieker de overgewicht prevalenties beschreven voor de drie etnische groepen volgens de in 2001 internationaal ontwikkelde criteria (voorgesteld door de IOTF) voor overgewicht en obesitas. De criteria zijn gebaseerd op internationale BMI referentie data uit 6 landen, waaronder de Nederlandse 1980 studie en daterend van vóór de overgewicht 'epidemie'. De gemiddelde overgewicht (obesitas) prevalenties voor Turkse jongens en meisjes waren 23.4% en 30.2% (5.2% en 7.2%), voor Marokkanen 15.8% en 24.5% (3.1% en 5.4%), voor Nederlandse 2-20 jarigen in de grote steden 12.6% en 16.5% (1.6% en 2.8%) en voor de overige Nederlandse jongeren 8.7% en 11.3% (0.8% en 1.4%). Voor alle kinderen in de grote steden waren er significante correlaties tussen overgewicht en etniciteit, opleiding van de ouders (-) en geslacht (+ meisjes). Het effect van ouderlijk opleidingsniveau verdween bij een multivariate analyse indien gecorrigeerd voor etniciteit en geslacht. Uit dit alles blijkt dat vooral de Turkse en Marokkaanse meisjes vergelijkbare prevalenties voor overgewicht hebben met Amerikaanse kinderen en dat individuele maar ook cultureel ingebedde preventie strategieën essentieel zijn om gezondheidsproblemen te voorkomen, met speciale aandacht voor kinderen in de grote steden.

In **Hoofdstuk 10** wordt uitvoeriger ingegaan op de methodiek waarmee in de 1997 groeistudie de referentie diagrammen zijn geconstrueerd (de LMS methode van Cole en Green). Als het model goed past en een passende Box Cox transformatie is gekozen, hebben de metingen in de referentiegroep een normale verdeling over alle leeftijden. De coëfficiënten van deze transformatie zijn 3 geleidelijk verlopende leeftijdsafhankelijke parameter curves voor de verdeling (L), de mediaan (M) en de variatie coëfficiënt (S). Elke keuze van de parameter curve is gerelateerd aan bepaalde kenmerken van de wormplot, namelijk de oorsprong van de worm, de helling en de vorm van de worm. De belangrijkste taak in de LMS methode is om de best passende en meest vloeiende vorm voor elke parameter curve te vinden. De wormplot kan hier een nuttig aandeel in hebben. De wormplot wordt gewoonlijk gebruikt als een algemeen diagnostisch hulpmiddel voor de analyse van residuen, waarbij de verschillen zichtbaar worden gemaakt tussen twee verdelingen, onder conditie van bepaalde covariaten. In dit hoofdstuk gaat het om de leeftijd als covariaat. Met behulp van de LMS methode en de wormplot zijn verschillende referentie curves voor een groot aantal anthropometrische metingen geconstrueerd. De wormplot kan nog verder ontwikkeld worden om de LMS methodiek enigszins doorzichtiger te maken.

In **Hoofdstuk 11** worden alle resultaten van de voorgaande hoofdstukken gecombineerd en bediscussieerd. Achtereenvolgens worden de resultaten besproken aan de hand van een aantal onderwerpen, waarbij zowel de gegevens van de Nederlandse, Turkse als Marokkaanse data zijn meegenomen: de opzet van de studie, de seculaire verandering van lengte, het gebruik van de target height en de aanpassing van de formule op de 1997 groeidata, de seculaire verschuiving in de puberteitsontwikkeling, de gevolgen van een toename van overgewicht bij de jeugd, de keuzes voor een optimale lay-out van de nieuwe groeidiagrammen, het gebruik van de verschillende diagrammen in de praktijk, de maatschappelijke consequenties van de resultaten van de Vierde Landelijke Groeistudie en tenslotte volgen een aantal aanbevelingen voor toekomstige groeistudies.

Appendix 1

Questionnaires

Appendix 1: Questionnaires

IDENTIFICATIEFORMULIER (0 tot 4 jaar) Organisatie:|__|__|__|PNR: |9|5| |__|__|__|__|

1. Nummer invuller |__|__|__|__|__|__|__|

2. Invuldatum |__|__| dag |__|__| maand |__|__| jaar

3. Geboortedatum kind |__|__| dag |__|__| maand |__|__| jaar

4. Geslacht

jongen	1
meisje	2

5. Regio

Noord	1
Oost	2
West	3
Zuid	4
Grote steden	5

6. Gemeentegrootte woonplaats: -

< 5.000	1
5.000 - < 20.000	2
20.000 - < 50.000	3
50.000 - < 100.000	4
100.000 - < 200.000	5
≥200.000 (grote stad)	6

7. Aard van het onderzoek

regulier consult arts (pgo)	1
regulier consult verpleegkundige (pvo)	2
pgo/pvo combinatiebureau	3
afzonderlijk uitgenodigd	4

8. Meegewerkt aan de peiling

ja	1 ga naar volgende pagina
nee	2

9. NON-RESPONS

verschenen en geweigerd		1
niet verschenen en geweigerd		2
niet verschenen	ga naar 10	3
verschenen, maar lengte en/of gewicht meting niet gelukt		4

VERVANGEN!

10. Reden niet verschijnen:

emigratie/remigratie	1
verhuizing	2
ziekte/ongeval	3
geen belangstelling	4
anders	5
onbekend	9

VRAGENLIJST ACHTERGRONDGEGEVENS (0 tot 4 jaar)

1. Geboorteland/land van herkomst biol. moeder
zie toelichting !

Nederland	ga naar 3	1
West-Europa	ga naar 3	2
Noord-Amerika	ga naar 3	3
Turkije		4
Marokko		5
Noord-Afrika		6

2. Verblijfsduur van de biol. moeder in NL

< 1 jaar	1
1 t/m 5 jaar	2
6 t/m 10 jaar	3
11 t/m 20 jaar	4
langer dan 20 jaar	5
onbekend	9

3. Geboorteland/land van herkomst biologische vader
zie toelichting !

-	Nederland	1
-	West-Europa	2
-	Noord-Amerika	3
-	Turkije	4
-	Marokko	5
-	Noord-Afrika	6

4. Aantal kinderen in het gezin
waarmee het kind is opgegroeid |__|__|
onbekend 99

5. Aantal kinderen van biol. |__|__|
moeder (inclusief dit kind)
onbekend 99

6. Plaats van het kind in de kinderrij |__|__|
(kinderen van de biologische moeder)
onbekend 99

7. Is het kind deel van een meerling?

nee	1
tweeling	2
drieling of meer	3
onbekend	9

8. Lengte van de biol. ouders
vader |__|__|__| cm
onbekend 9

moeder |__|__|__| cm
onbekend 9

9. Opvoedingssituatie

twee-oudergezin		1
één-oudergezin		2
co-ouderschap (50/50)		3
twee ouder (figuren) van hetzelfde geslacht		4
familie/kennissen	ga naar 14	5
onbekend	ga naar 14	9

10. Sociale status moeder (figuur)

buitenshuis werkend 1
ga naar 10a

niet buitenshuis werkend 2
ga naar 10b
geen moeder (figuur) in het gezin
aanwezig ga naar 12 8
onbekend 9

10a Indien buitenshuis werkend

volledige baan	1
deeltijd baan, >16 uur per week	2
deeltijd baan, ≤16 uur per week	3

10b Indien niet buitenshuis werkend
moeder (figuur)

werkloos/zoekend	1
arbeidsongeschikt	2
huisvrouw	3
pensioen/VUT	4
nog met een (beroeps)opleiding bezig	5
onbekend	9

11. Hoogste voltooide schoolopleiding

(geen) lagere school	1
lbo, mavo	2
havo, vwo, mbo	3
hbo, universiteit, hogeschool	4
afgeronde vervolgopleiding in het buitenland	5
anders	6
onbekend	9

12. Sociale status vader(figuur)
buitenshuis werkend 1
ga naar 12a

niet buitenshuis werkend 2
ga naar 12b
geen vader (figuur) in het gezin aanwezig
ga naar 14 8
onbekend 9

12a Indien buitenshuis werkend
volledige baan 1
deeltijd baan,
> 16 uur per week 2
deeltijd baan,
≤ 16 uur per week 3
onbekend 9

12b Indien niet buitenshuis werkend
werkloos/zoekend 1
arbeidsongeschikt 2
huisman 3
pensioen/VUT 4
nog met een (beroeps)opleiding
bezig 5
onbekend 9

13. Hoogste voltooide schoolopl. vader(figuur)
(geen) lagere school 1
lbo, mavo 2
havo, vwo, mbo 3
hbo, universiteit, hogeschool 4
afgeronde vervolgopleiding in het
buitenland 5
anders 6
onbekend 9

14. Als er bij één of meer vragen 'onbekend' is ingevuld,
wat is daarvan de voornaamste reden?

- taalprobleem 1
- weigering 2
- kind zonder ouders op consult 3

VRAGENLIJST GEZONDHEID EN MELKVOEDING (0 tot 4 jaar)

1.Is uw kind de afgelopen 12 mnd een aaneengesloten periode van ≥ 7 dagen geweest?
ja 1
nee ga naar 3 2
onbekend ga naar 3 9

2.Hoe vaak heeft hij/zij zo'n periode gehad?
__|__| maal
onbekend 99

3. Heeft uw kind in de afgelopen mnd medicijnen gebruikt? (op recept voorgeschreven door huisarts of specialist) (uitgezonderd gebitsregulatie en refractieafwijking)
N.B. Fluoride, vitamines A, A/D en K tellen niet mee
ja 1
nee 2
onbekend 9

4 Is het kind op dit moment in behandeling bij (huis)arts, specialist of fysiotherapeut?
ja 1
nee 2
onbekend 9

5. Heeft uw kind suikerziekte?
behandeling met insuline
ja 1
nee 2
onbekend 9

6. Heeft uw kind epilepsie?
behandeling met anti-epileptica
ja 1
nee 2
onbekend 9

7. Heeft uw kind een groeistoornis (gehad) of een ziekte die de groei beïnvloed kan hebben?

ja	1	diagnose:
nee	2	
onbekend	9	

8. Is uw kind vanwege zijn/haar lengte ooit behandeld met medicijnen door de kinderarts?

ja	1	preparaat:
nee	2	
onbekend	9	

9. Heeft uw kind ooit langer dan 1 jaar (min of meer) ononderbroken (orale) corticosteroïden geslikt?

ja	1	preparaat:
nee	2	
onbekend	9	

10. Zwangerschapsduur |__|__| weken
onbekend 9

11. Geboortegewicht van het kind |__|__|__|__| gram
onbekend 9

12. Heeft de moeder gerookt tijdens de zwangerschap?

nooit	1
minder dan 1 sigaret per dag	2
1 t/m 5 sigaretten per dag	3
6 t/m 10 sigaretten per dag	4
11 t/m 15 sigaretten per dag	5
16 sigaretten of meer per dag	6
onbekend	9

13. Heeft moeder alcohol gedronken tijdens de zwangerschap?

nooit	1
1 glas of minder per week	2
2 t/m 7 glazen per week	3
8 t/m 14 glazen per week	4
15 of meer glazen per week	5
onbekend	9

14. Heeft het kind ooit borstvoeding gekregen?

ja		1
ja, maar binnen 2 weken gestopt	ga naar 19	2
nooit ga naar 19		3
onbekend ga naar 19		9

15. Krijgt uw kind op dit moment nog als melkvoeding uitsluitend borstvoeding?

nee		1
ja	ga naar biometrie	2
onbekend	ga naar biometrie	9

16. Tot welke leeftijd kreeg uw kind uitsluitend borstvoeding als melkvoeding |__|__| maanden
onbekend 99

17. Krijgt uw kind op dit moment een combinatie van borstvoeding en kunstvoeding?

nee	1
ga naar 19	2
onbekend ga naar 19	9

18. Tot welke lft kreeg uw kind een combi van borstvoeding en kunstvoeding?
__|__| maanden

nooit gehad	88
onbekend	99

19. Welke kunstvoeding geeft u uw kind op dit moment of kreeg uw kind als laatste kunstvoeding?
(bij deze vraag zijn meerdere antwoorden mogelijk)

- Nutrilon Premium 1
- Nutrilon Forte 1

-	Farilon	1
-	Nutrilon A.R.	1
-	Nutrilon Pepti (Plus)	1
-	Nutrilon Soya (Plus)	1
-	Nutrilon Laag Lactose	1
-	Frisolac	1
-	Frisovom	1
-	Frisopep 1/2	1
-	Frisosoy	1
-	Nutrilon Plus	1
-	Frisomel	1
-	Aptamil 1	1
-	Aptamil 2	1
-	anders	1
-	n.v.t.	8
-	onbekend	9

BIOMETRIE (0 tot 2 jaar)

1. Algemeen oordeel over de bouw van het kind

gewicht:	-	extreem licht	1
	-	normaal	2
	-	extreem zwaar	3
lengte:	-	extreem kort	1
	-	normaal	2
	-	extreem lang	3

2. lichaamsgewicht: |__|__|__|__|__| gram

3. nummer weegschaal: |__|__|__|

4. lichaamslengte: A. liggend: (tot 2 jaar) |__|__|__|,|__| cm

   B. staand: (ook vanaf het moment dat het kind kan staan) |__|__|__|,|__| cm

5. zithoogte: liggend: |__|__|__|,|__| cm

6. taille-omtrek: A. staand: |__|__|,|__| cm

   B. liggend: (indien het kind niet kan staan) |__|__|,|__| cm

7. heupomtrek: A. staand: |__|__|,|__| cm

   B. liggend: (indien het kind niet kan staan) |__|__|,|__| cm

8. hoofdomtrek: |__|__|,|__| cm

BIOMETRIE (2 tot 4 jaar)

1. Algemeen oordeel over de bouw van het kind

gewicht:
- extreem licht 1
- normaal 2
- extreem zwaar 3

lengte:
- extreem kort 1
- normaal 2
- extreem lang 3

2. lichaamsgewicht: |__|__|__|__|__|__| gram

3. nummer weegschaal: |__|__|__|

4. lichaamslengte: (alleen staand) |__|__|__|,|__| cm

5. zithoogte: (alleen zittend) |__|__|__|,|__| cm

6. taille-omtrek: (alleen staand) |__|__|,|__| cm

7. heupomtrek: (alleen staand) |__|__|,|__| cm

8. hoofdomtrek: |__|__|,|__| cm

9. hoogte van de stoel: (gebruikt bij meting van de zithoogte) |__|__|__|,|__| cm

CONCLUSIE (0 tot 4 jaar)

1. Gezondheidstoestand van het kind
   - goed 1
   - matig 2
   - slecht 3

2. Is er naar aanleiding van het consult een verwijsadvies naar de huisarts of anderszins gegeven? (uitgezonderd gebitsregulatie en refractieafwijking)
   - ja 1
   - nee 2
   - onbekend 9

3. Bestaat er aanleiding voor extra aandacht vanuit de jeugdgezondheidszorg, ongeacht de reden?
   - ja 1
   - nee 2
   - onbekend 9

IDENTIFICATIEFORMULIER (4 t/m 20 jaar) Organisatie: |__|__|__| PNR: |9|5| |__|__|__|__|

1. Nummer invuller |__|__|__|__|__|__|__|

2. Invuldatum |__|__| dag |__|__| maand |__|__| jaar

3. Geboortedatum kind/jongere |__|__| dag |__|__| maand |__|__| jaar

4.	Geslacht	jongen	1
		meisje	2
5.	Regio	Noord	1
		Oost	2
		West	3
		Zuid	4
		Grote steden	5

6.	Gemeentegrootte woonplaats:	< 5.000		1
		5.000 - < 20.000		2
		20.000 - < 50.000		3
		50.000 - < 100.000		4
		100.000 - < 200.000		5
		≥ 200.000 (grote stad)		6
7.	Aard van het onderzoek	pgo		1
		pvo		2
		afzonderlijk uitgenodigd		4
8.	Meegewerkt aan de peiling	ja	ga naar volgende pagina	1
		nee		2

9.	NON-RESPONS		10.	Reden niet verschijnen:	
	verschenen en geweigerd	1		emigratie/remigratie	1
	niet verschenen en geweigerd	2		verhuizing	2
	niet verschenen ga naar 10	3		ziekte/ongeval	3
	verschenen, maar lengte en/of gewicht meting niet gelukt	4		geen belangstelling	4
				anders	5
				onbekend	9

VERVANGEN!

VRAGENLIJST ACHTERGRONDGEGEVENS (4 t/m 20 jaar)

1. Schoolgaand

ja		1
leerlingwezen		2
combinatie van betaald werk en onderwijs		3
nee	ga naar 3	4
onbekend	ga naar 3	9

2. Onderwijsniveau

basisschool	1	algemene brugklas	6	MBO	12
lbo/vbo	2	lbo/mavo brugklas	7	HBO	13
mavo	3	mavo/havo brugklas	8	universiteit	14
havo	4	mavo/havo/vwo brugklas	9	anders	15
vwo	5	havo/vwo brugklas	10	onbekend	99
		(voortgezet) spec. onderwijs	11		

ga door naar vraag 5

3. Hoogste voltooide schoolopleiding

(geen) lagere school	1
lbo, mavo	2
havo, vwo, mbo	3
hbo, universiteit	4
anders	5
onbekend	9

4. Werksituatie

volledige baan	1
deeltijd baan, > 16 uur per week	2
deeltijd baan ≤ 16 uur per week	3
werkloos/-zoekend	4
arbeidsongeschikt	5
huisvrouw/man	6
onbekend	9

5. Geboorteland/land van herkomst biol. moeder zie toelichting!

Nederland	ga naar 7	1
West-Europa	ga naar 7	2
Noord-Amerika	ga naar 7	3
Turkije		4
Marokko		5
-Noord-Afrika		6

6.Verblijfsduur van de biol. moeder in NL

< 1 jaar	1
1 t/m 5 jaar	2
6 t/m 10 jaar	3
11 t/m 20 jaar	4
langer dan 20 jaar	5
onbekend	9

7. Geboorteland/land van herkomst biologische vader, zie toelichting.

Nederland	1
West-Europa	2
Noord-Amerika	3
Turkije	4
Marokko	5
Noord-Afrika	6

8. Aantal kinderen in het gezin waarmee het kind is opgegroeid| __|__|
(inclusief dit kind)

onbekend 99

9.Aantal kinderen van de biologische moeder |__|__|

onbekend 99

10. Plaats van het kind in de kinderrij (kinderen van de biologische moeder) |__|__|

onbekend 99

11. Is het kind deel van een meerling?

nee	1
tweeling	2
drieling of meer	3
onbekend	9

12. Lengte van de biol. ouders

vader |__|__|__| cm
onbekend 9

moeder |__|__|__| cm
onbekend 9

13. Opvoedingssituatie

twee-oudergezin		1
één-oudergezin		2
co-ouderschap (50/50)		3
twee ouder(figuren) van hetzelfde geslacht		4
familie/kennissen	ga naar 18	5
woont zelfstandig	ga naar 18	6
anders	ga naar 18	7
onbekend	ga naar 18	9

14. Sociale status moeder(figuur)

buitenshuis werkend ga naar 14a	1
niet buitenshuis werkend ga naar 14b	2
geen moeder(figuur) in het gezin aanwezig ga naar 16	8
onbekend	9

14a Indien buitenshuis werkend

volledige baan	1
deeltijd baan, >16 uur per week	2
deeltijd baan, ≤16 uur per week	3

14b Indien niet buitenshuis werkend

werkloos/zoekend	1
arbeidsongeschikt	2
huisvrouw	3
pensioen/VUT	4
nog met een (beroeps)opleiding bezig	5
onbekend	9

15. Hoogste voltooid schoolopleiding moeder (figuur)

(geen) lagere school	1
lbo, mavo	2
havo, vwo, mbo	3
hbo, universiteit, hogeschool	4
afgeronde vervolgopleiding in het buitenland	5
anders	6
onbekend	9

16 Sociale status vader(figuur)

buitenshuis werkend ga naar 12a	1
niet buitenshuis werkend ga naar 12b	2
geen vader(figuur) in het gezin aanwezig ga naar 14	8
onbekend	9

16a Indien buitenshuis werkend

volledige baan	1
deeltijd baan, > 16 uur per week	2
deeltijd baan, ≤ 16 uur per week	3
onbekend	9

16b Indien niet buitenshuis werkend

werkloos/zoekend	1
arbeidsongeschikt	2
huisman	3
pensioen/VUT	4
nog met een (beroeps)opleiding bezig	5
onbekend	9

17. Hoogste voltooide schoolopl. vader(figuur)

(geen) lagere school	1
lbo, mavo	2
havo, vwo, mbo	3
hbo, universiteit, hogeschool	4
afgeronde vervolgopleiding in het buitenland	5
anders	6
onbekend	9

18. Als er bij één of meer vragen 'onbekend' is ingevuld, wat is daarvan de voornaamste reden?

taalprobleem	1
weigering	2
kind zonder ouders op consult	3

VRAGENLIJST ZIEKTEN EN MEDICIJNGEBRUIK (4 tot 9 jaar)

1.Is uw kind de afgelopen 12 mnd een aaneengesloten periode van ≥ 7 dagen geweest?

ja		1
nee	ga naar 3	2
onbekend	ga naar 3	9

2.Hoe vaak heeft hij/zij zo'n periode gehad?

__|__| maal	
onbekend	99

3. Heeft uw kind in de afgelopen mnd medicijnen gebruikt? (op recept voorgeschreven door huisarts of specialist) (uitgezonderd gebitsregulatie en refractieafwijking)
N.B. Fluoride, vitamines A, A/D en K tellen niet mee

ja	1
nee	2
onbekend	9

4 Is het kind op dit moment in behandeling bij (huis)arts, specialist of fysiotherapeut?

ja	1
nee	2
onbekend	9

5. Heeft uw kind suikerziekte?
behandeling met insuline

ja	1
nee	2
onbekend	9

6. Heeft uw kind epilepsie?
behandeling met anti-epileptica

ja	1
nee	2
onbekend	9

7. Heeft uw kind een groeistoornis (gehad) of een ziekte die de groei beïnvloed kan hebben?

ja	1	diagnose:
nee	2	
onbekend	9	

8. Geboortegewicht van het kind |__|__|__|__| gram

onbekend 9

9 Heeft uw kind een groeistoornis (gehad) of een ziekte die de groei beïnvloed kan hebben?

ja	1	diagnose:
nee	2	
onbekend	9	

10. Is uw kind vanwege zijn/haar lengte ooit behandeld met medicijnen door de kinderarts?

ja	1	preparaat:
nee	2	
onbekend	9	

11. Heeft uw kind ooit langer dan 1 jaar (min of meer) ononderbroken (orale) corticosteroïden geslikt?

ja	1	preparaat:
nee	2	
onbekend	9	

VRAGENLIJST ZIEKTEN EN MEDICIJNGEBRUIK (9 t/m 20 jaar)

1. Ben je in de afgelopen 12 maanden een aaneengesloten periode van 7 dagen of langer ziek geweest?

ja		1
nee	ga naar 3	2
onbekend	ga naar 3	9

2. Hoe vaak heb je zo'n periode gehad?
|__|__| maal
onbekend 99

3. Heb je in de afgelopen maanden medicijnen gebruikt? (op recept voorgeschreven door huisarts of specialist) N.B. Fluoride, vitamines A, A/D en K tellen niet mee
ja 1
nee 2
onbekend 9

4 Ben je op dit moment in behandeling bij (huis)arts, specialist of fysiotherapeut? (uitgezonderd gebitsregulatie en refractieafwijking)
ja 1
nee 2
onbekend 9

5. Heb je suikerziekte? Ben je in behandeling met insuline?
ja 1
nee 2
onbekend 9

6. Heb je epilepsie? Ben je in behandeling met anti-epileptica
ja 1
nee 2
onbekend 9

7. Geboortegewicht van het kind |__|__|__|__| gram

onbekend 9

VRAGENLIJST ZIEKTEN EN MEDICIJNGEBRUIK (9 t/m 20 jaar) - VERVOLG

8. Heb je een groeistoornis (gehad) of een ziekte die de groei beïnvloed kan hebben?
ja 1 diagnose:
nee 2
onbekend 9

9. Ben je vanwege je lengte ooit behandeld met medicijnen door de kinderarts?
ja 1 preparaat:
nee 2
onbekend 9

10. Heb je ooit langer dan 1 jaar (min of meer) ononderbroken (orale) corticosteroïden geslikt?
ja 1 preparaat:
nee 2
onbekend 9

VRAGENLIJST JEUGDPUISTJES (9 t/m 20 jaar)

1. Heb je jeugdpuistjes of acne (gehad)?

ja, op dit moment	1
op dit moment niet, maar in het verleden wel	2
nee, ga naar naar 4	3

2. Hoe vervelend vind (vond) je de jeugdpuistjes of acne?

helemaal niet vervelend	1
een beetje vervelend	2
redelijk vervelend	3
erg vervelend	4

3. Hoe lang heb je al jeugdpuistjes of acne (gehad)?

< ½ jaar	1
½ jaar - 1 jaar	2
1 jaar - 2 jaar	3
≥2 jaar	4
onbekend	9

4. Aantal comedonen (meeëters) per gezichtshelft

geen	1
minder dan 5	2
5 tot en met 9	3
10 tot en met 24	4
25 of meer	5

5. Aantal papels per gezichtshelft

geen	1
minder dan 5	2
5 tot en met 9	3
10 of meer	4

6. Aantal pustels per gezichtshelft

geen	1
minder dan 2	2
2 tot en met 4	3
5 of meer	4

Indien vraag 1 met 'op dit moment niet, maar in het verleden wel' of 'nee' is beantwoord en/of er bij inspectie geen comedonen, papels of pustels aanwezig zijn, doorgaan naar vraag 15

7. Knijp jij je papels/pustels meestal uit?

ja	1
nee	2
n.v.t.	8

8. Knijp jij je comedonen (meeëters) meestal uit?

ja	1
nee	2
n.v.t.	8

9. Gebruik je op dit moment één of meer van de volgende middelen om de jeugdpuistjes te verminderen? (bij deze vraag zijn meerdere antwoorden mogelijk)

a.	Clearasil	1
b.	Acne cure creme	1
c.	andere anti-acne lijn	1
d.	benzoylperoxide (Benzac, Pauline-lijn)	1
e.	pure alcohol	1
f.	marmerzeep/zwavelzeep	1
g.	ruwe washand	1
h.	dieet	1
i.	homeopatische middelen	1

10. Ben je op dit moment onder behandeling voor jeugdpuistjes?
(bij deze vraag zijn meerdere antwoorden mogelijk)

a.	niet onder behandeling	ga naar 15	1
b.	huisarts	ga naar 11	1
c.	dermatoloog	ga naar 11	1
d.	schoonheidsspecialist of huidtherapeut	ga naar 15	1
e.	alternatieve behandelwijzen	ga naar 15	1

11. Gebruik je op dit moment uitwendige geneesmiddelen die door een arts zijn voorgeschreven?

ja		1
nee	ga naar 13	2

12. Gebruik je op dit moment de volgende uitwendige geneesmiddelen:
(bij elk onderdeel van deze vraag een atwoord invullen)

JA, effect van de behandeling:

		NEE	wordt erger	geen verschil	wordt minder erg	weet ik (nog) niet	
a.	benzoylperoxide						
	zoals Benzac	1	1	1	1	1	1
b.	retinoïden (AcidAVit)	1	1	1	1	1	1
c.	antibiotica (tetracycline/minocyl/	1	1	1	1	1	1
	erythromycine deppers)	1	1	1	1	1	1
d.	anders	1	1	1	1	1	1
e.	onbekend	1	1	1	1	1	1

13. Gebruik je op dit moment geneesmiddelen die je moet innemen die door een arts zijn voorgeschreven?

ja		1
nee	ga naar 15	2

14. Gebruik je op dit moment de volgende geneesmiddelen die je moet innemen:
(bij elk onderdeel van deze vraag een antwoord invullen)

			JA, effect van de behandeling:				
		NEE	wordt erger	geen verschil	wordt minder erg	weet ik (nog) niet	
a.	antibiotica (tetracycline/minocycline)	1	1	1	1	1	1
b.	retinoïden (RoaccutaneR)	1	1	1	1	1	1
c.	Diane-35R-pil	1	1	1	1	1	1
d.	anders	1	1	1	1	1	1
e.	onbekend	1	1	1	1	1	1

15. Localisatie van de jeugdpuistjes op het moment van onderzoek (bij inspectie)
(bij deze vraag zijn meerdere antwoorden mogelijk)

a.	gezicht	1
b.	borst	1
c.	rug	1
d.	geen jeugdpuistjes	1

BIOMETRIE (4 tot 9 jaar)

1. Algemeen oordeel over de bouw van het kind

gewicht:	-	extreem licht	1
	-	normaal	2
	-	extreem zwaar	3
lengte:	-	extreem kort	1
	-	normaal	2
	-	extreem lang	3

2. lichaamsgewicht: |__|__|,|__| kg

3. nummer weegschaal: |__|__|__|

4. lichaamslengte: |__|__|__|,|__| cm

5. zithoogte: |__|__|__|,|__| cm

6. taille omtrek: |__|__|__|,|__| cm

7. heupomtrek: |__|__|__|,|__| cm

8. hoofdomtrek: |__|__|,|__| cm

9. hoogte van de stoel: (gebruikt bij de meting van de zithoogte) |__|__|__|,|__| cm

BIOMETRIE (9 t/m 20 jaar)

1. Algemeen oordeel over de bouw van het kind

gewicht:	extreem licht	1
	normaal	2
	extreem zwaar	3

lengte:	-	extreem kort	1
	-	normaal	2
	-	extreem lang	3

2. lichaamsgewicht: |__|__|,|__| kg

3. nummer weegschaal: |__|__|__|

4. lichaamslengte: |__|__|__|,|__| cm

5. zithoogte: |__|__|__|,|__| cm

6. taille omtrek: |__|__|__|,|__| cm

7. heupomtrek: |__|__|__|,|__| cm

8. hoofdomtrek: |__|__|,|__| cm

9. hoogte van de stoel: (gebruikt bij de meting van de zithoogte) |__|__|__|,|__| cm

Puberteitskenmerken

Jongens:

10. Ontwikkeling genitalia

G1	1
G2	2
G3	3
G4	4
G5	5
weigering	6
onbekend	9

11. Pubesbeharing

P1	1
P2	2
P3	3
P4	4
P5	5
P6	6
weigering	7
onbekend	9

12. Volume rechter testikel |__|__| ml.

(borstklierontwikkeling)	
weigering	77
slechts 1 testikel aanwezig	88
onbekend	99

13. Gynaecomastie

ja	1
nee	2
weigering	3
onbekend	9

Meisjes:

14. Borstontwikkeling

M1	1
M2	2
M3	3
M4	4
M5	5
Weigering	6
onbekend	9

15. Pubesbeharing

P1	1
P2	2
P3	3
P4	4
P5	5
P6	6
weigering	7
onbekend	9

16. Ben je al eens ongesteld geweest?

ja	1
nee	2
onbekend	9

17. Gebruik je op dit moment de pil?

ja	1
nee	2
onbekend	9

De volgende vragen alleen invullen indien een Turks of Marokkaans meisje weigert de borstontwikkeling en pubesbeharing te laten onderzoeken. In dit geval kan het meisje zelf de betreffende foto's aanwijzen. N.B. Alleen in uiterste gevallen gebruiken!

18. Borstontwikkeling

M1	1
M2	2
M3	3
M4	4
M5	5
Weigering	6
onbekend	9

19. Pubesbeharing

P1	1
P2	2
P3	3
P4	4
P5	5
P6	6
weigering	7
onbekend	9

CONCLUSIE (4 tot 9 jaar)

1. Gezondheidstoestand van het kind

goed	1
matig	2
slecht	3

2. Is er naar aanleiding van het consult een verwijsadvies naar de huisarts of anderszins gegeven? (uitgezonderd gebitsregulatie en refractieafwijking)

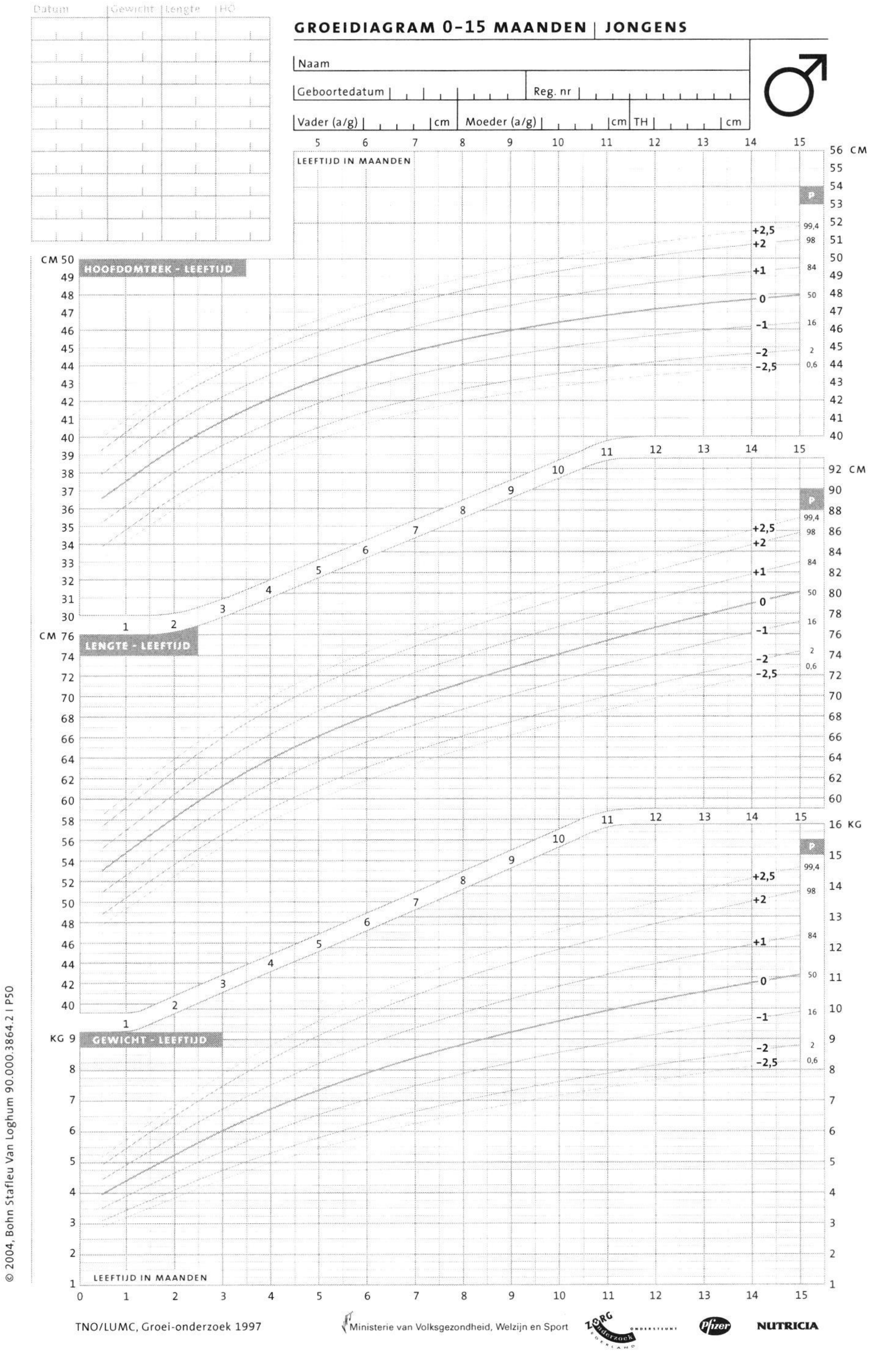
ja	1
nee	2
onbekend	9

3. Bestaat er aanleiding voor extra aandacht vanuit de jeugdgezondheidszorg, ongeacht de reden?

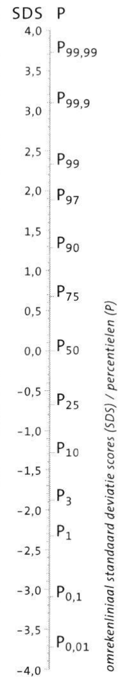
ja	1
nee	2
onbekend	9

Appendix 2

Growth Diagrams


GROEIDIAGRAM 0-15 MAANDEN | JONGENS
Datum | Gewicht | Lengte | HO
Naam
Geboortedatum
Reg. nr
Vader (a/g) cm
Moeder (a/g) cm
TH cm
LEEFTIJD IN MAANDEN
HOOFDOMTREK - LEEFTIJD
LENGTE - LEEFTIJD
GEWICHT - LEEFTIJD
CM
KG
P
+2,5 +2 +1 0 -1 -2 -2,5
99,4 98 84 50 16 2 0,6
© 2004, Bohn Stafleu Van Loghum 90.000.3864.2 I P50
TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
ZORG onderzoek NEDERLAND
Pfizer
NUTRICIA

UITLEG STANDAARD DEVIATIE SCORES



De standaard deviatie (SD) is een maat voor de spreiding van meetwaarden rondom het gemiddelde van een populatie, waarbij is aangenomen dat de meetwaarden een normale verdeling hebben: dit geldt bij benadering voor lengte en hoofdomtrek. De standaard deviatie score (SDS) is het aantal standaard deviaties boven of onder het gemiddelde. Een SDS van 0 geeft dan het gemiddelde van een populatie weer (dit komt overeen met de mediaan, P_{50}). Een positieve SDS duidt op een meetwaarde boven het gemiddelde. Een negatieve SDS betekent een meetwaarde beneden het gemiddelde. Hoe hoger of lager de score, hoe uitzonderlijker deze meetwaarde is. De meeste kinderen zullen meetwaarden in het gebied tussen -2 SDS en +2 SDS hebben (tussen P_2 en P_{98}). De buitenste referentielijnen in het groeidiagram, ±2,5 SDS, geven de extreme meetwaarden weer in een normale populatie ($P_{0,6}$ en $P_{99,4}$). Kinderen met extremere meetpunten kunnen goed met SDS worden weergegeven in het groeidiagram doordat de SDS-referentielijnen op gelijke afstand van elkaar liggen. Een verschuiving van -1 SDS naar -2 SDS is even groot in centimeters als een verschuiving van -2 SDS naar -3 SDS. De SDS-waarden kunnen rechts op de SDS-referentielijnen afgelezen worden, de overeenkomende percentielwaarden kunnen rechts naast het diagram worden afgelezen. De lengte in cm kan op elke leeftijd worden omgezet in een SDS met behulp van de volgende formule:

♂

$$\textbf{lengte SDS} = \frac{\textbf{lengte (cm) - gemiddelde lengte voor leeftijd en geslacht } (\bar{X})}{\textbf{SD voor leeftijd en geslacht (SD)}}$$

Mnd	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$\bar{X}$	54,7	58,1	61,2	63,8	66,1	68,0	69,7	71,2	72,7	74,0	75,3	76,6	77,7	78,9	80,0
SD	2,2	2,3	2,4	2,4	2,5	2,5	2,5	2,6	2,6	2,7	2,7	2,8	2,8	2,8	2,9

TARGET HEIGHT

Voor het beoordelen van het groeipatroon van een kind is de lengte van de ouders een belangrijk hulpmiddel. In het diagram kan de lengte ingevuld worden met een "g" indien de ouders door u zelf zijn gemeten, met een "a" als de lengte anamnestisch is verkregen. Op basis van de lengte van beide ouders kan de uiteindelijk te bereiken lengte voor een kind rekenkundig benaderd worden, de zogenaamde target height (TH). Gezonde kinderen hebben hun eindlengte in een gebied van ±1,3 SD rondom de TH. Dit is ongeveer 9 cm boven en onder de TH (TH-range).

$$\textbf{TH jongen (cm)} = \frac{\textbf{vaderlengte + [moederlengte + 13]}}{\textbf{2}} \textbf{ + 4,5}$$

Het gemiddelde lengteverschil tussen vader en moeder is 13 cm. Het generatieverschil voor jongens en meisjes is 4,5 cm.

Samengevat:

TH jongen (cm) = gemiddelde ouderlengte + 11

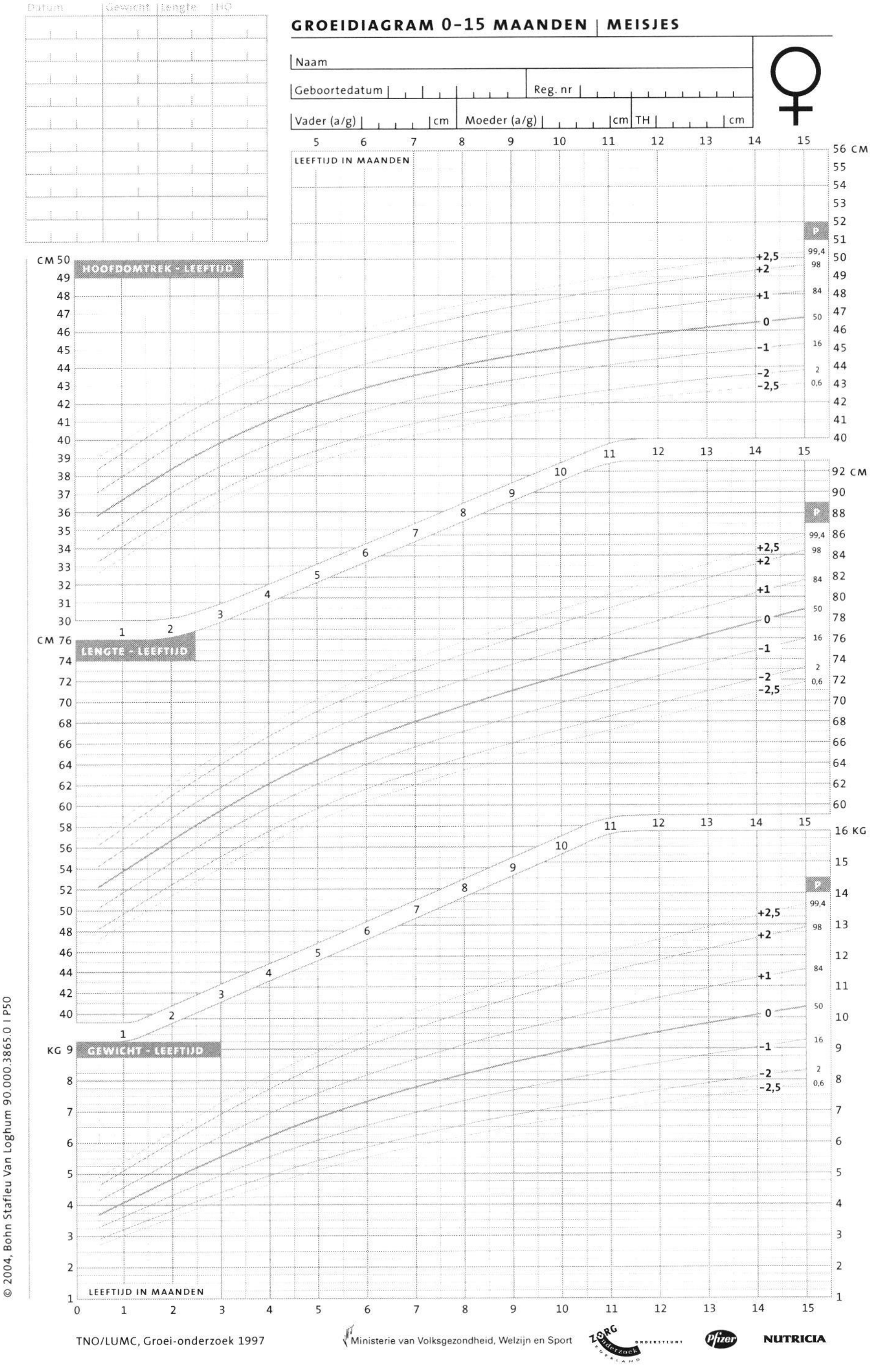
De TH kan ook in SDS worden weergegeven:

TH-SDS jongen = (TH - 184,0) / 7,1

♂ ***Omrekentabel:***

TH met daaronder de overeenkomende TH-SDS waarde

TH (cm)	165	167	169	171	173	175	177	179	181	183	185	187	189	191	193	195	197	199	201	203
TH-SDS (cm)	-2,7	-2,4	-2,1	-1,8	-1,6	-1,3	-1,0	-0,7	-0,4	-0,1	+0,1	+0,4	+0,7	+1,0	+1,3	+1,6	+1,8	+2,1	+2,4	+2,7



GROEIDIAGRAM 0-15 MAANDEN | MEISJES
Naam
Geboortedatum
Reg. nr
Vader (a/g)
Moeder (a/g)
TH
cm
LEEFTIJD IN MAANDEN
HOOFDOMTREK - LEEFTIJD
LENGTE - LEEFTIJD
GEWICHT - LEEFTIJD
56 CM
92 CM
16 KG
CM 50
CM 76
KG 9
+2,5
+2
+1
0
-1
-2
-2,5
99,4
98
84
50
16
2
0,6
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TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
NUTRICIA

UITLEG STANDAARD DEVIATIE SCORES

De standaard deviatie (SD) is een maat voor de spreiding van meetwaarden rondom het gemiddelde van een populatie, waarbij is aangenomen dat de meetwaarden een normale verdeling hebben: dit geldt bij benadering voor lengte en hoofdomtrek. De standaard deviatie score (SDS) is het aantal standaard deviaties boven of onder het gemiddelde. Een SDS van 0 geeft dan het gemiddelde van een populatie weer (dit komt overeen met de mediaan, P_{50}). Een positieve SDS duidt op een meetwaarde boven het gemiddelde. Een negatieve SDS betekent een meetwaarde beneden het gemiddelde. Hoe hoger of lager de score, hoe uitzonderlijker deze meetwaarde is. De meeste kinderen zullen meetwaarden in het gebied tussen -2 SDS en +2 SDS hebben (tussen P_2 en P_{98}). De buitenste referentielijnen in het groeidiagram, ±2,5 SDS, geven de extreme meetwaarden weer in een normale populatie ($P_{0,6}$ en $P_{99,4}$). Kinderen met extremere meetpunten kunnen goed met SDS worden weergegeven in het groeidiagram doordat de SDS-referentielijnen op gelijke afstand van elkaar liggen. Een verschuiving van -1 SDS naar -2 SDS is even groot in centimeters als een verschuiving van -2 SDS naar -3 SDS. De SDS-waarden kunnen rechts op de SDS-referentielijnen afgelezen worden, de overeenkomende percentielwaarden kunnen rechts naast het diagram worden afgelezen. De lengte in cm kan op elke leeftijd worden omgezet in een SDS met behulp van de volgende formule:

♀

$$\textbf{lengte SDS} = \frac{\textbf{lengte (cm) - gemiddelde lengte voor leeftijd en geslacht } (\bar{X})}{\textbf{SD voor leeftijd en geslacht (SD)}}$$

Mnd	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$\bar{X}$	53,8	56,7	59,5	62,1	64,4	66,4	68,1	69,7	71,1	72,5	73,8	75,1	76,4	77,6	78,8
SD	2,0	2,1	2,2	2,3	2,3	2,4	2,4	2,5	2,5	2,5	2,6	2,6	2,7	2,7	2,8

TARGET HEIGHT

Voor het beoordelen van het groeipatroon van een kind is de lengte van de ouders een belangrijk hulpmiddel. In het diagram kan de lengte ingevuld worden met een "g" indien de ouders door u zelf zijn gemeten, met een "a" als de lengte anamnestisch is verkregen. Op basis van de lengte van beide ouders kan de uiteindelijk te bereiken lengte voor een kind rekenkundig benaderd worden, de zogenaamde target height (TH). Gezonde kinderen hebben hun eindlengte in een gebied van ±1,3 SD rondom de TH. Dit is ongeveer 9 cm boven en onder de TH (TH-range).

$$\textbf{TH meisje (cm)} = \frac{\textbf{moederlengte + [vaderlengte - 13]}}{\textbf{2}} \textbf{ + 4,5}$$

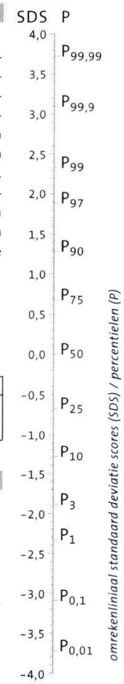
Het gemiddelde lengteverschil tussen vader en moeder is 13 cm. Het generatieverschil voor jongens en meisjes is 4,5 cm.

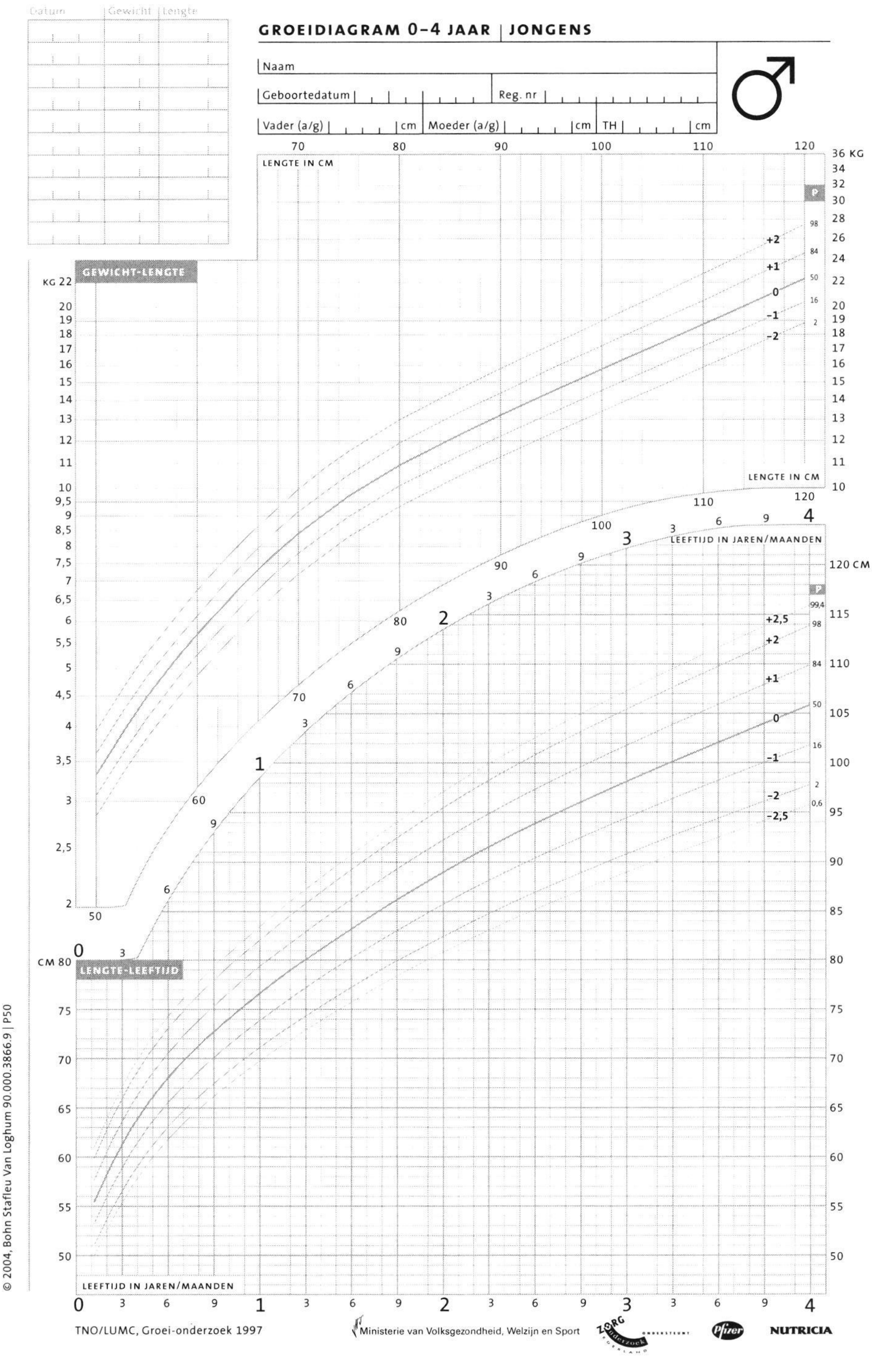
Samengevat:
TH meisje (cm) = gemiddelde ouderlengte - 2

De TH kan ook in SDS worden weergegeven:
TH-SDS meisje = (TH - 170,6) / 6,5

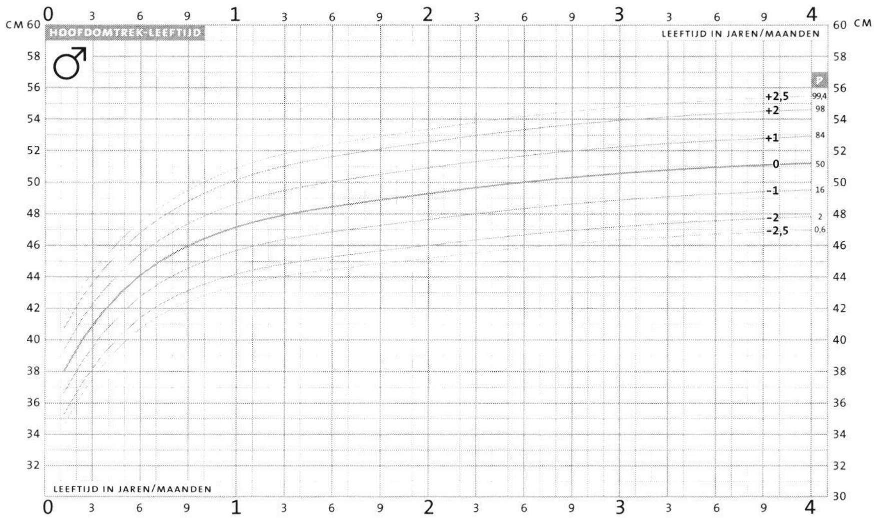
♀ *Omrekentabel:*
TH met daaronder de overeenkomende TH-SDS waarde

TH (cm)	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184	186	188
TH-SDS (cm)	-2,6	-2,3	-2,0	-1,6	-1,3	-1,0	-0,7	-0,4	-0,1	+0,2	+0,5	+0,8	+1,1	+1,5	+1,8	+2,1	+2,4	+2,7

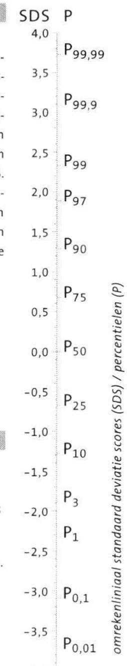




Datum | Gewicht | Lengte
GROEIDIAGRAM 0–4 JAAR | JONGENS
Naam
Geboortedatum
Reg. nr
Vader (a/g) cm
Moeder (a/g) cm
TH cm
LENGTE IN CM
GEWICHT-LENGTE
LENGTE-LEEFTIJD
LEEFTIJD IN JAREN/MAANDEN
KG
CM
TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
NUTRICIA
© 2004, Bohn Stafleu Van Loghum 90.000.3866.9 | P50



UITLEG STANDAARD DEVIATIE SCORES



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♂

Jaar	0,5	1	1,5	2	2,5	3	3,5	4
$\bar{X}$	68,0	76,6	83,2	88,9	93,8	98,1	102,0	105,8
SD	2,5	2,8	3,0	3,3	3,5	3,7	3,8	4,0

TARGET HEIGHT

Voor het beoordelen van het groeipatroon van een kind is de lengte van de ouders een belangrijk hulpmiddel. In het diagram kan de lengte ingevuld worden met een "g" indien de ouders door u zelf zijn gemeten, met een "a" als de lengte anamnestisch is verkregen. Op basis van de lengte van beide ouders kan de uiteindelijk te bereiken lengte voor een kind rekenkundig benaderd worden, de zogenaamde target height (TH). Gezonde kinderen hebben hun eindlengte in een gebied van ±1,3 SD rondom de TH. Dit is ongeveer 9 cm boven en onder de TH (TH-range).

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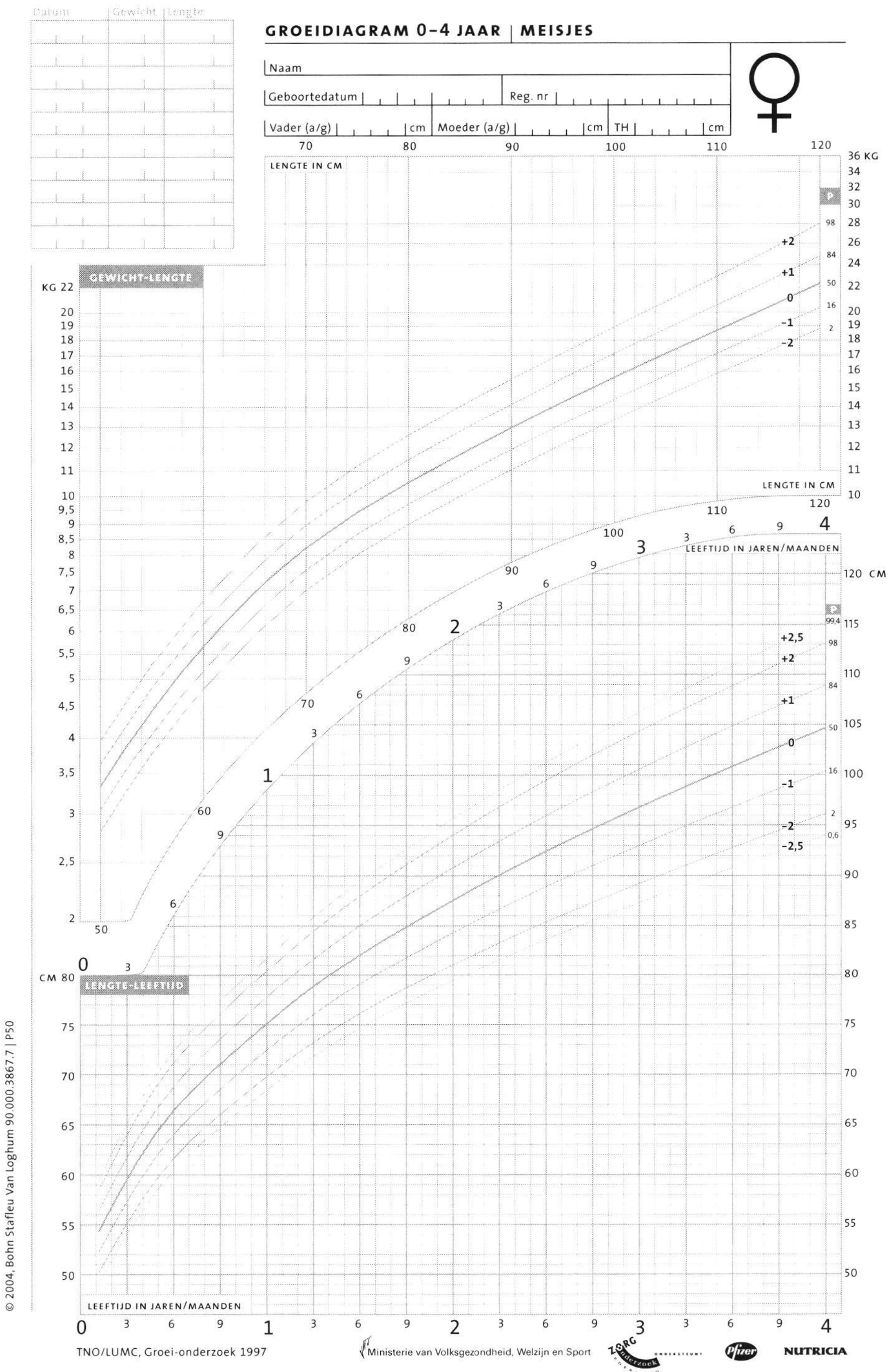

Datum | Gewicht | Lengte
GROEIDIAGRAM 0-4 JAAR | MEISJES
Naam
Geboortedatum
Reg. nr
Vader (a/g) cm
Moeder (a/g) cm
TH cm
GEWICHT-LENGTE
LENGTE IN CM
KG 22
36 KG
LENGTE-LEEFTIJD
CM 80
120 CM
LEEFTIJD IN JAREN/MAANDEN
TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
NUTRICIA
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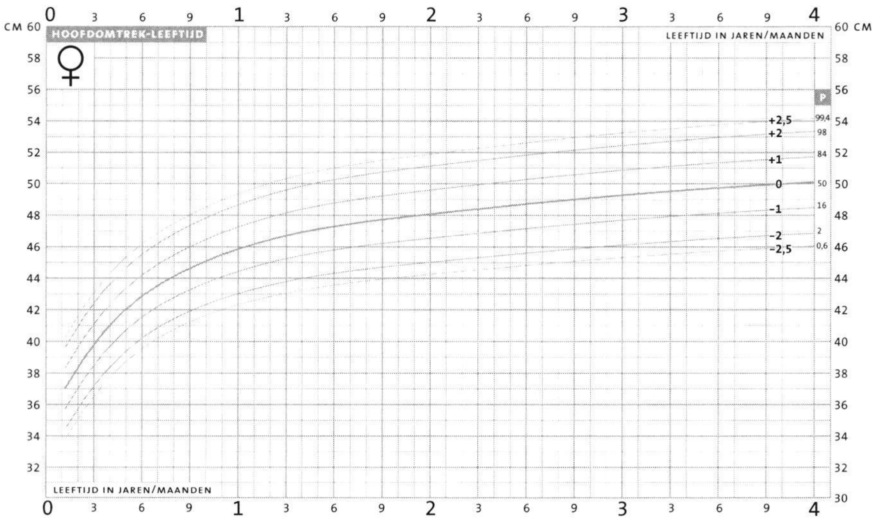

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♀

Jaar	0,5	1	1,5	2	2,5	3	3,5	4
$\bar{X}$	66,4	75,1	82,1	87,5	92,3	96,7	100,7	104,5
SD	2,4	2,6	2,9	3,2	3,5	3,7	3,9	4,2

TARGET HEIGHT

Voor het beoordelen van het groeipatroon van een kind is de lengte van de ouders een belangrijk hulpmiddel. In het diagram kan de lengte ingevuld worden met een "g" indien de ouders door u zelf zijn gemeten, met een "a" als de lengte anamnestisch is verkregen. Op basis van de lengte van beide ouders kan de uiteindelijk te bereiken lengte voor een kind rekenkundig benaderd worden, de zogenaamde target height (TH). Gezonde kinderen hebben hun eindlengte in een gebied van ±1,3 SD rondom de TH. Dit is ongeveer 9 cm boven en onder de TH (TH-range).

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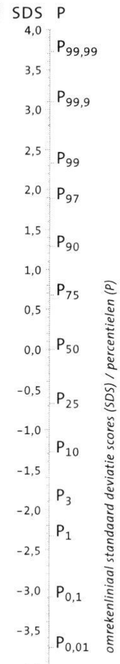
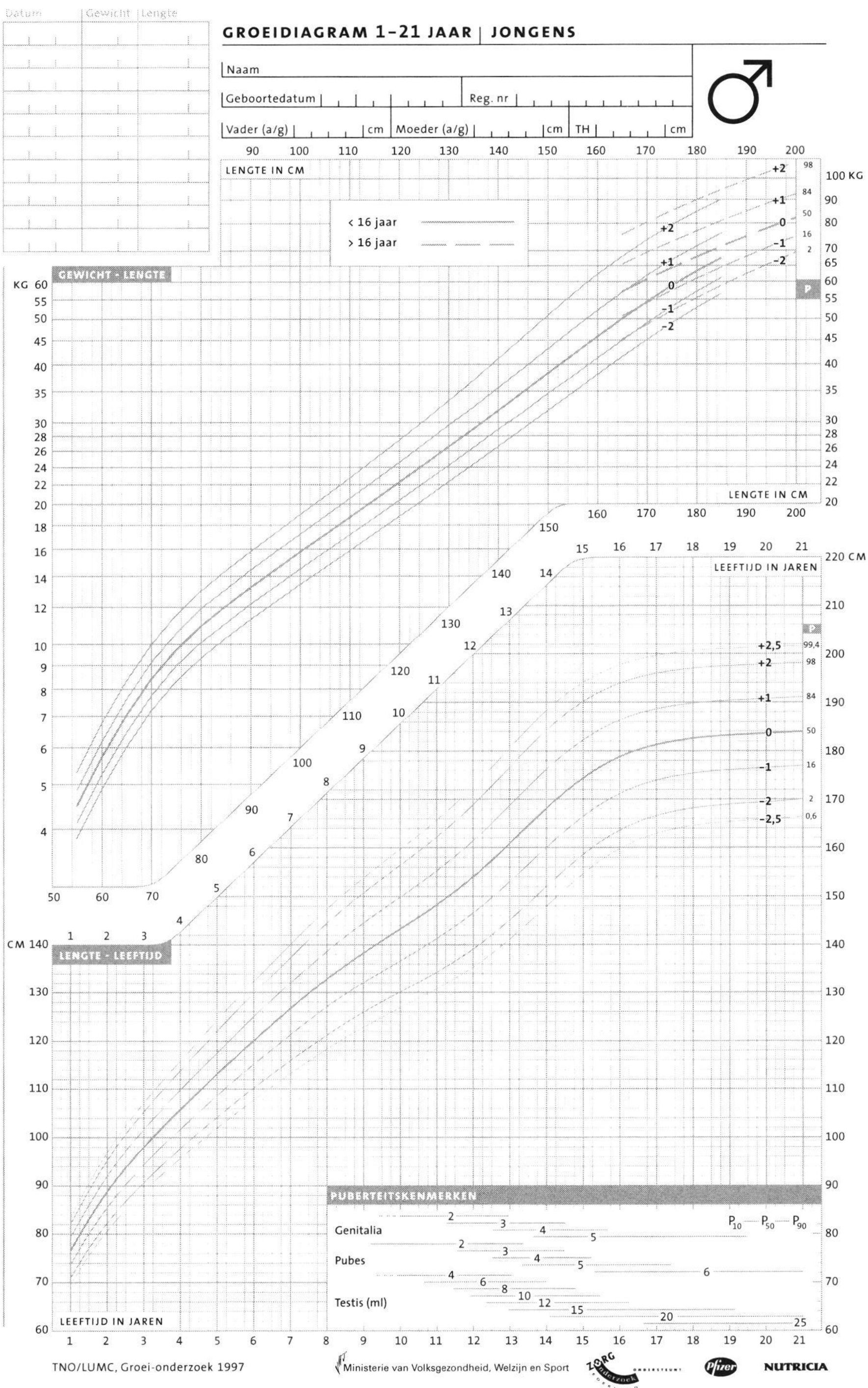
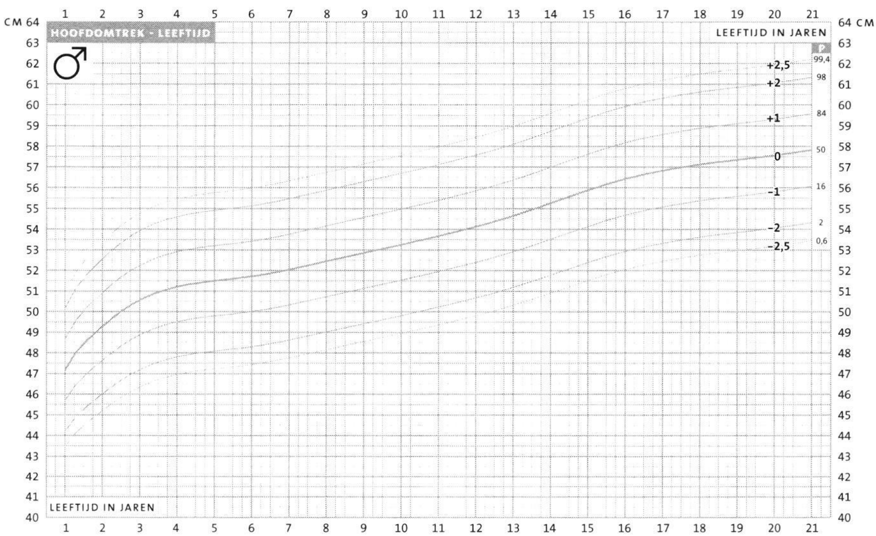




GROEIDIAGRAM 1–21 JAAR | JONGENS
Naam
Geboortedatum
Reg. nr
Vader (a/g)
Moeder (a/g)
TH
cm
Datum
Gewicht
Lengte
LENGTE IN CM
< 16 jaar
> 16 jaar
GEWICHT - LENGTE
KG
LENGTE - LEEFTIJD
CM
LEEFTIJD IN JAREN
PUBERTEITSKENMERKEN
Genitalia
Pubes
Testis (ml)
TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
NUTRICIA



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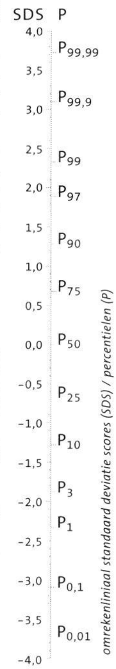
Jaar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
$\bar{X}$	76,6	88,9	98,1	105,8	113,1	120,1	126,6	132,8	138,3	143,2	148,2	154,0	160,9	168,2	174,4	178,7	181,3	182,6	183,2	183,6	184,0
SD	2,8	3,3	3,7	4,0	4,5	4,9	5,4	5,8	6,2	6,6	7,0	7,5	7,9	8,1	7,9	7,6	7,3	7,2	7,2	7,1	7,1



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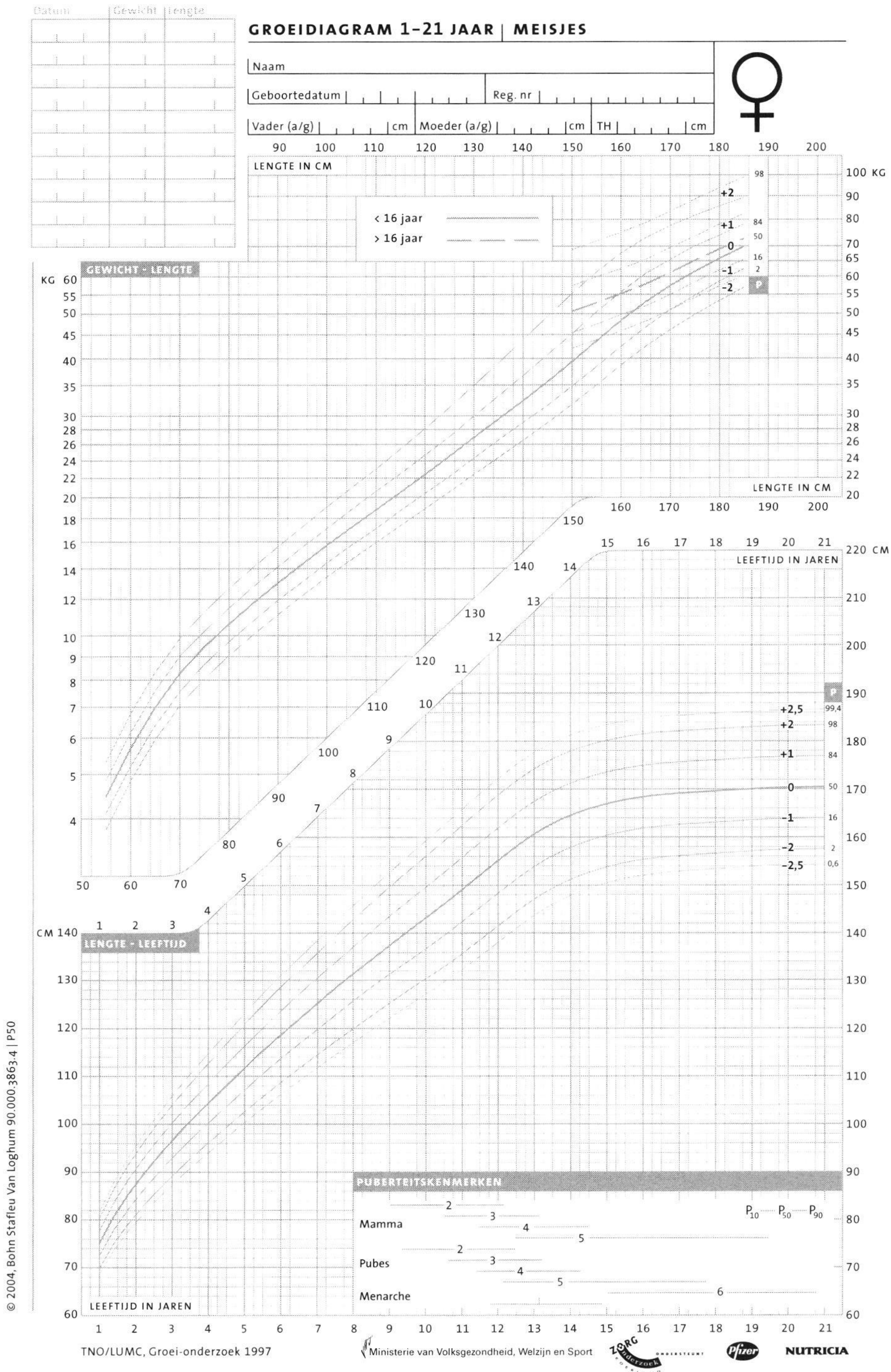
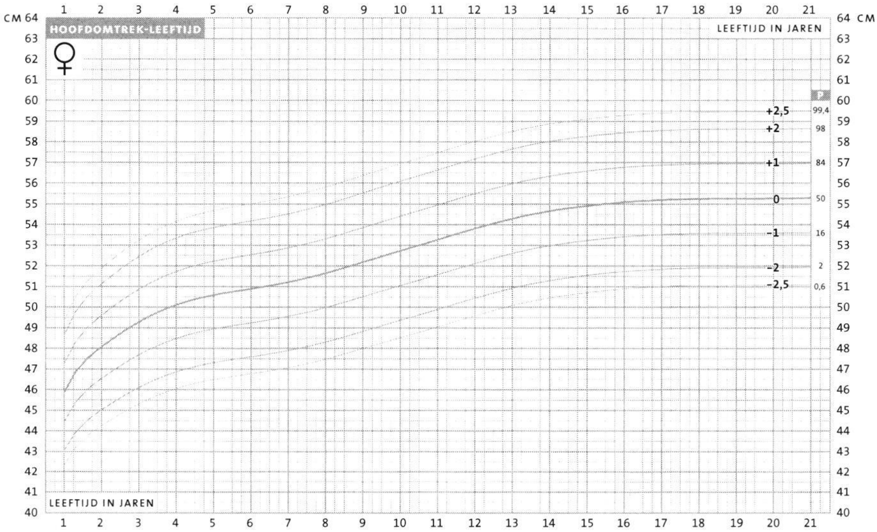
TH (cm)	165	167	169	171	173	175	177	179	181	183	185	187	189	191	193	195	197	199	201	203
TH-SDS (cm)	-2,7	-2,4	-2,1	-1,8	-1,6	-1,3	-1,0	-0,7	-0,4	-0,1	+0,1	+0,4	+0,7	+1,0	+1,3	+1,6	+1,8	+2,1	+2,4	+2,7

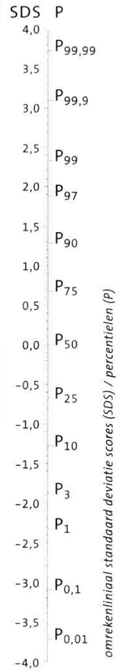


GROEIDIAGRAM 1–21 JAAR | MEISJES
Naam
Geboortedatum
Reg. nr
Vader (a/g)
cm
Moeder (a/g)
cm
TH
cm
Datum
Gewicht
Lengte
LENGTE IN CM
< 16 jaar
> 16 jaar
GEWICHT - LENGTE
KG
100 KG
LENGTE IN CM
LEEFTIJD IN JAREN
220 CM
LENGTE - LEEFTIJD
CM 140
PUBERTEITSKENMERKEN
Mamma
Pubes
Menarche
LEEFTIJD IN JAREN
TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
Pfizer
NUTRICIA
© 2004, Bohn Stafleu Van Loghum 90.000.3863.4 | P50



UITLEG STANDAARD DEVIATIE SCORES

De standaard deviatie (SD) is een maat voor de spreiding van meetwaarden rondom het gemiddelde van een populatie, waarbij is aangenomen dat de meetwaarden een normale verdeling hebben: dit geldt bij benadering voor lengte en hoofdomtrek. De standaard deviatie score (SDS) is het aantal standaard deviaties boven of onder het gemiddelde. Een SDS van 0 geeft dan het gemiddelde van een populatie weer (dit komt overeen met de mediaan, P_{50}). Een positieve SDS duidt op een meetwaarde boven het gemiddelde. Een negatieve SDS betekent een meetwaarde beneden het gemiddelde. Hoe hoger of lager de score, hoe uitzonderlijker deze meetwaarde is. De meeste kinderen zullen meetwaarden in het gebied tussen -2 SDS en +2 SDS hebben (tussen P_2 en P_{98}). De buitenste referentielijnen in het groeidiagram, ±2,5 SDS, geven de extreme meetwaarden weer in een normale populatie ($P_{0,6}$ en $P_{99,4}$). Kinderen met extremere meetpunten kunnen goed met SDS worden weergegeven in het groeidiagram doordat de SDS-referentielijnen op gelijke afstand van elkaar liggen. Een verschuiving van -1 SDS naar -2 SDS is even groot in centimeters als een verschuiving van -2 SDS naar -3 SDS. De SDS-waarden kunnen rechts op de SDS-referentielijnen afgelezen worden, de overeenkomende percentielwaarden kunnen rechts naast het diagram worden afgelezen. De lengte in cm kan op elke leeftijd worden omgezet in een SDS met behulp van de volgende formule:



♀

$$\textbf{lengte SDS} = \frac{\textbf{lengte (cm) - gemiddelde lengte voor leeftijd en geslacht } (\bar{X})}{\textbf{SD voor leeftijd en geslacht (SD)}}$$

Jaar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
$\bar{X}$	75,1	87,5	96,7	104,5	111,8	118,7	125,2	131,5	137,5	143,3	149,2	155,3	160,8	164,7	167,1	168,6	169,3	169,8	170,2	170,5	170,6
SD	2,6	3,2	3,7	4,2	4,6	5,0	5,4	5,8	6,1	6,4	6,7	6,8	6,8	6,7	6,6	6,6	6,5	6,5	6,5	6,5	6,5

TARGET HEIGHT

Voor het beoordelen van het groeipatroon van een kind is de lengte van de ouders een belangrijk hulpmiddel. In het diagram kan de lengte ingevuld worden met een "g" indien de ouders door u zelf zijn gemeten, met een "a" als de lengte anamnestisch is verkregen. Op basis van de lengte van beide ouders kan de uiteindelijk te bereiken lengte voor een kind rekenkundig benaderd worden, de zogenaamde target height (TH). Gezonde kinderen hebben hun eindlengte in een gebied van ±1,3 SD rondom de TH. Dit is ongeveer 9 cm boven en onder de TH (TH-range).

$$\textbf{TH meisje (cm)} = \frac{\textbf{moederlengte + [vaderlengte - 13]}}{\textbf{2}} \textbf{ + 4,5}$$

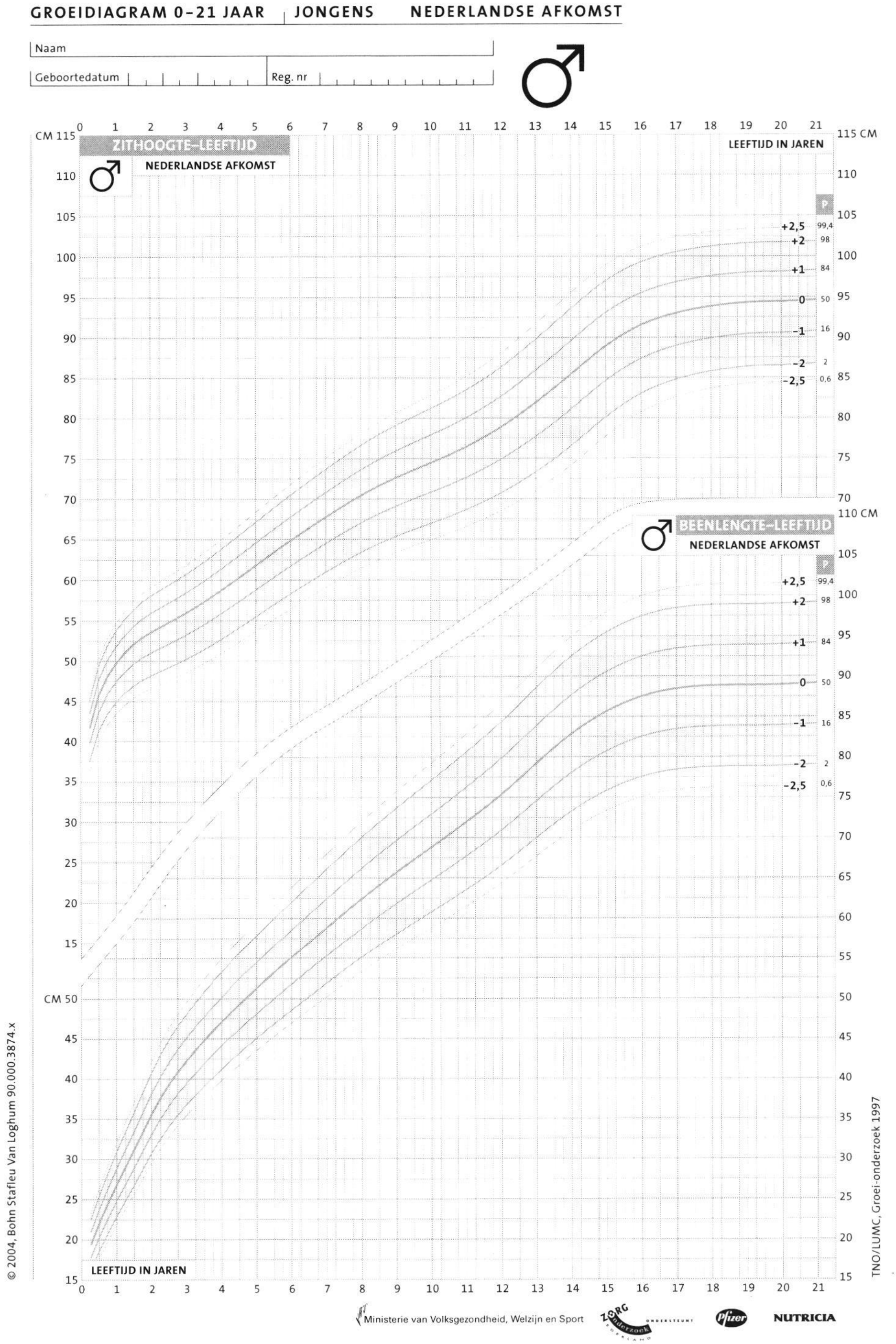
Het gemiddelde lengteverschil tussen vader en moeder is 13 cm. Het generatieverschil voor jongens en meisjes is 4,5 cm.

Samengevat:
TH meisje (cm) = gemiddelde ouderlengte - 2

De TH kan ook in SDS worden weergegeven:
TH-SDS meisje = (TH - 170,6) / 6,5

♀ ***Omrekentabel:***
TH met daaronder de overeenkomende TH-SDS waarde

TH (cm)	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184	186	188
TH-SDS (cm)	-2,6	-2,3	-2,0	-1,6	-1,3	-1,0	-0,7	-0,4	-0,1	+0,2	+0,5	+0,8	+1,1	+1,5	+1,8	+2,1	+2,4	+2,7


GROEIDIAGRAM 0-21 JAAR
JONGENS
NEDERLANDSE AFKOMST
Naam
Geboortedatum
Reg. nr
ZITHOOGTE-LEEFTIJD
NEDERLANDSE AFKOMST
LEEFTIJD IN JAREN
CM 115
115 CM
P
+2,5
+2
+1
0
-1
-2
-2,5
99,4
98
84
50
16
2
0,6
110 CM
BEENLENGTE-LEEFTIJD
NEDERLANDSE AFKOMST
CM 50
LEEFTIJD IN JAREN
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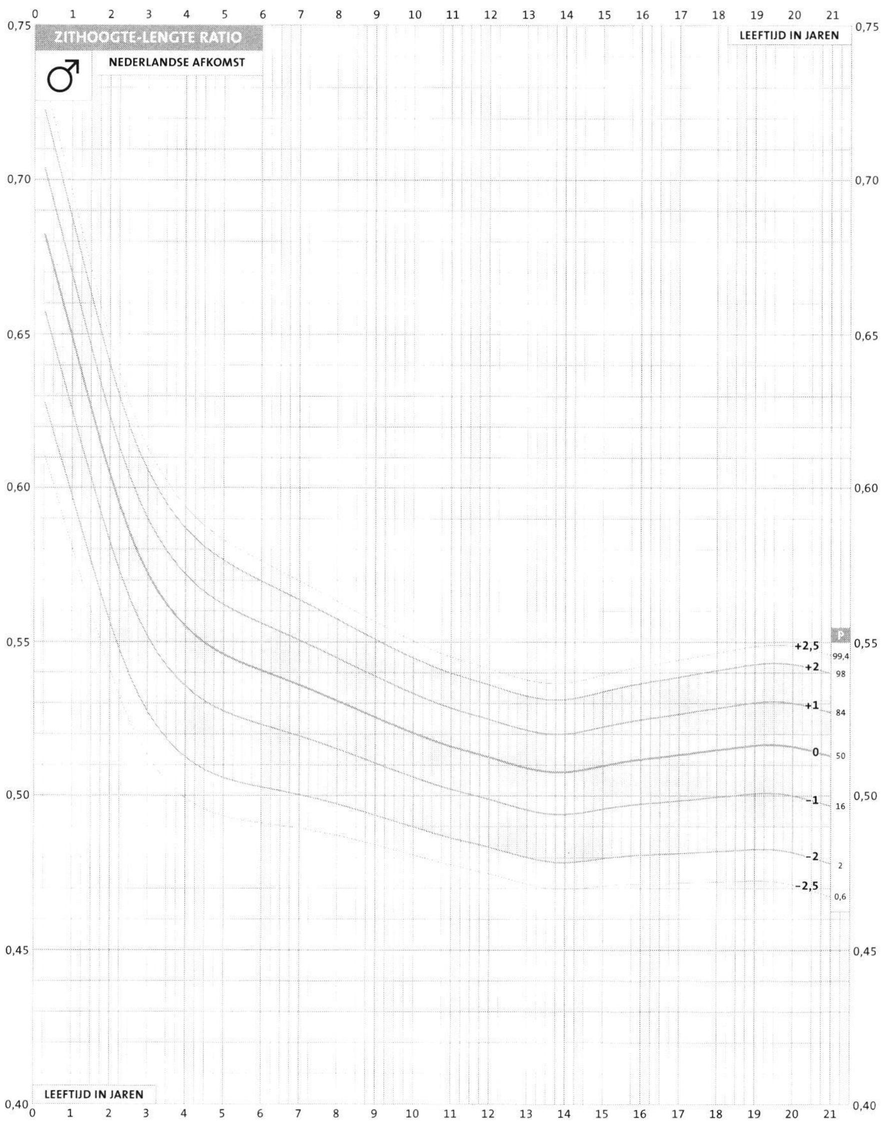
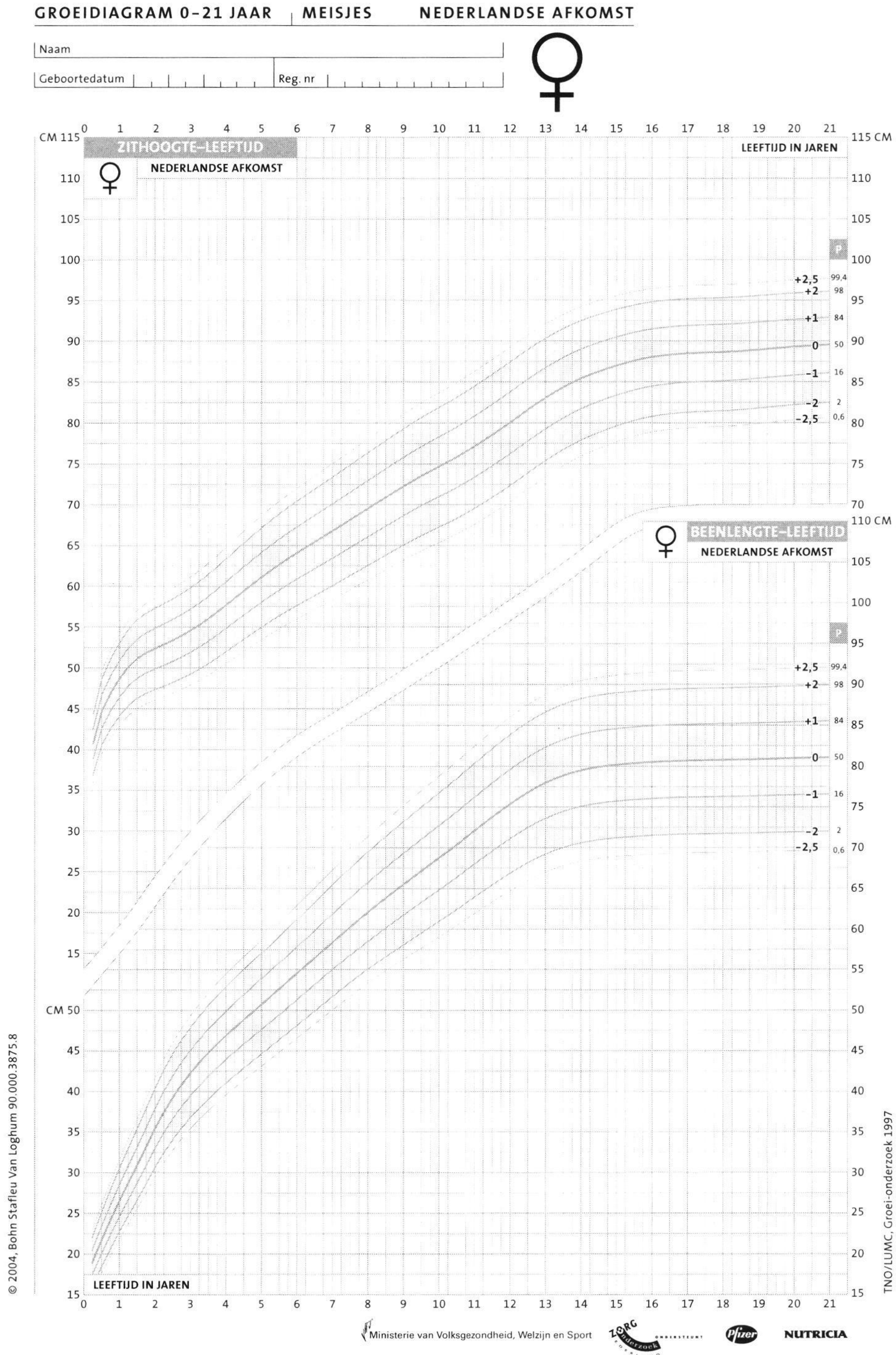
TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
NUTRICIA



TOELICHTING

De zithoogte en beenlengte zijn maten om disproporties (afwijkende lichaamsverhoudingen) op te sporen. Kinderen tot 2 jaar worden liggend gemeten. Het kind ligt op de rug in de meetbak met het hoofd tegen de hoofdplak. De benen worden gebogen en opgetild zodat ze een hoek van 90 graden met de romp maken. De voetenplank wordt tegen de beide billen (tubera ischiadica) geschoven en de **kruin-stuitlengte** wordt afgelezen. Vanaf 2 jaar zit het kind met gestrekte rug op een stoel/bankje, met billen en schouders tegen de muur. De voeten moeten op de grond of een voetsteun kunnen steunen, zodat de benen een hoek van 90 graden met het lichaam vormen. Het hoofd wordt zo gehouden dat een denkbeeldige lijn van de bovenkant van de uitwendige gehoorgang naar de onderkant van de oogkas (Frankfurter vlak) horizontaal verloopt. Het kind maakt zich groot door in te ademen en de hoogte van de kruin wordt gemeten. De **zithoogte** is de afgelezen hoogte minus de stoelhoogte. De **beenlengte** wordt berekend door de zithoogte van de totale lichaamslengte af te trekken.

De lichaamsverhoudingen kunnen beoordeeld worden met de ratio voor **zithoogte/totale lichaamslengte**. Wanneer deze ratio buiten + of – 2 SDS valt, kan van disproportie worden gesproken. Hierbij dient echter te worden bedacht dat lange kinderen gemiddeld lange benen hebben en kleine kinderen korte benen.


GROEIDIAGRAM 0–21 JAAR
MEISJES
NEDERLANDSE AFKOMST
Naam
Geboortedatum
Reg. nr
ZITHOOGTE–LEEFTIJD
NEDERLANDSE AFKOMST
LEEFTIJD IN JAREN
BEENLENGTE–LEEFTIJD
NEDERLANDSE AFKOMST
LEEFTIJD IN JAREN
CM 115
115 CM
110 CM
CM 50
P
+2,5
+2
+1
0
-1
-2
-2,5
99,4
98
84
50
16
2
0,6
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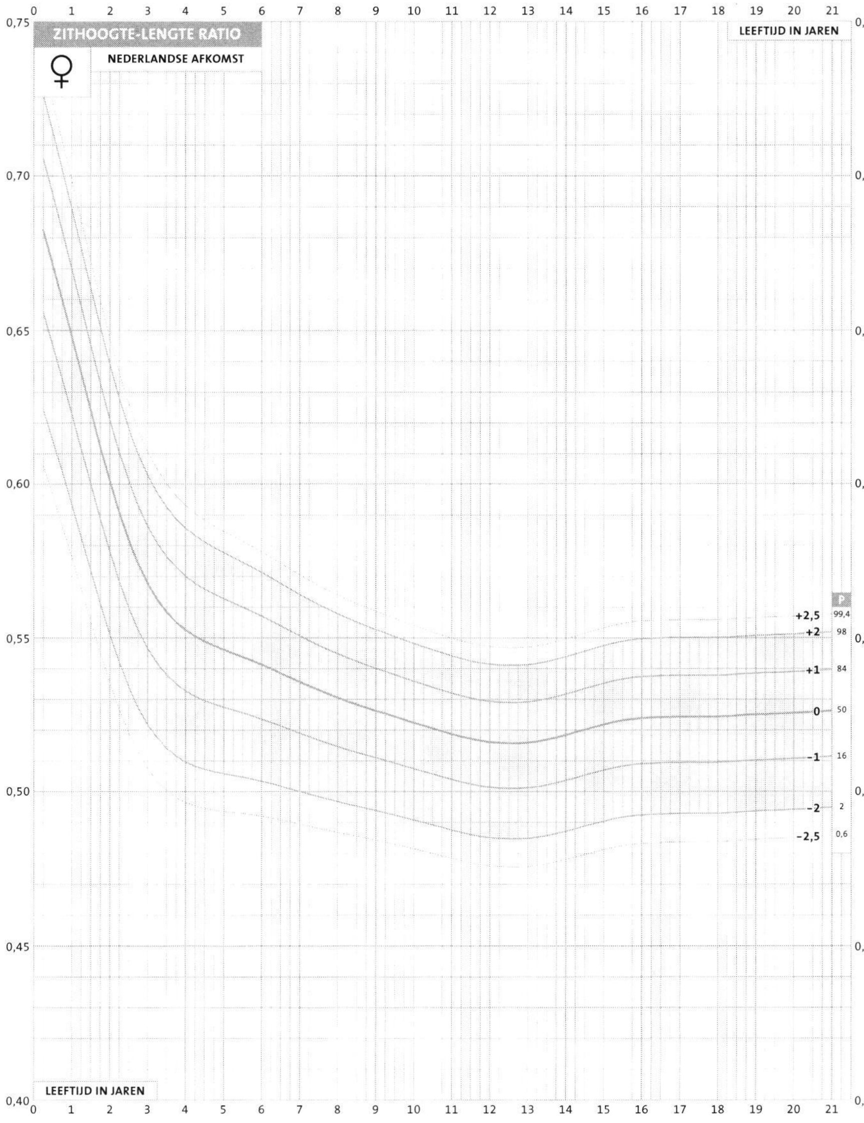
TNO/LUMC, Groei-onderzoek 1997
Ministerie van Volksgezondheid, Welzijn en Sport
NUTRICIA



TOELICHTING

De zithoogte en beenlengte zijn maten om disproporties (afwijkende lichaamsverhoudingen) op te sporen. Kinderen tot 2 jaar worden liggend gemeten. Het kind ligt op de rug in de meetbak met het hoofd tegen de hoofdplak. De benen worden gebogen en opgetild zodat ze een hoek van 90 graden met de romp maken. De voetenplank wordt tegen de beide billen (tubera ischiadica) geschoven en de **kruin-stuitlengte** wordt afgelezen. Vanaf 2 jaar zit het kind met gestrekte rug op een stoel/bankje, met billen en schouders tegen de muur. De voeten moeten op de grond of een voetsteun kunnen steunen, zodat de benen een hoek van 90 graden met het lichaam vormen. Het hoofd wordt zo gehouden dat een denkbeeldige lijn van de bovenkant van de uitwendige gehoorgang naar de onderkant van de oogkas (Frankfurter vlak) horizontaal verloopt. Het kind maakt zich groot door in te ademen en de hoogte van de kruin wordt gemeten. De **zithoogte** is de afgelezen hoogte minus de stoelhoogte. De **beenlengte** wordt berekend door de zithoogte van de totale lichaamslengte af te trekken.

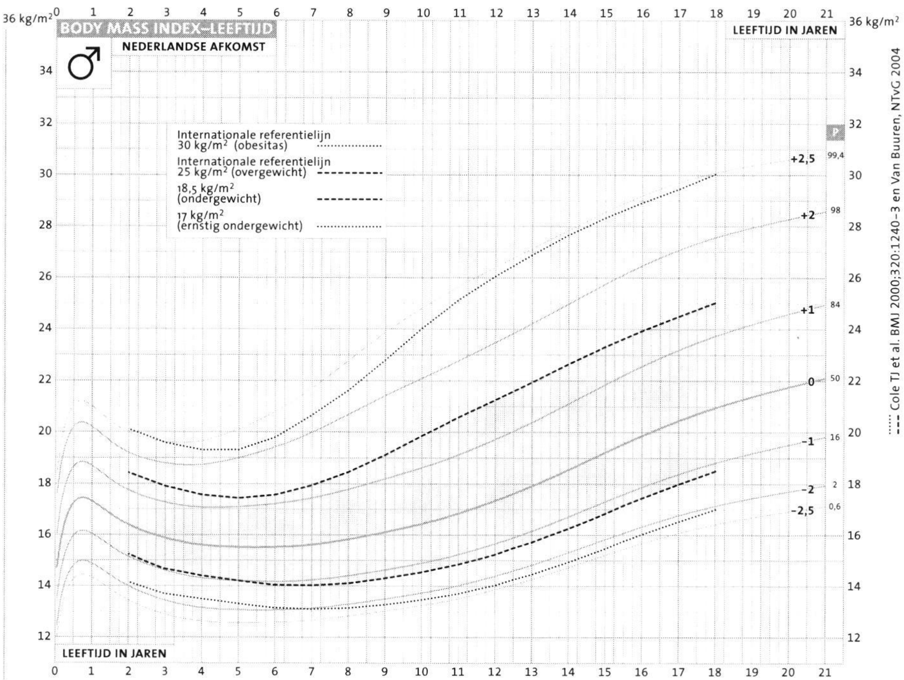
De lichaamsverhoudingen kunnen beoordeeld worden met de ratio voor **zithoogte/totale lichaamslengte**. Wanneer deze ratio buiten + of – 2 SDS valt, kan van disproportie worden gesproken. Hierbij dient echter te worden bedacht dat lange kinderen gemiddeld lange benen hebben en kleine kinderen korte benen.

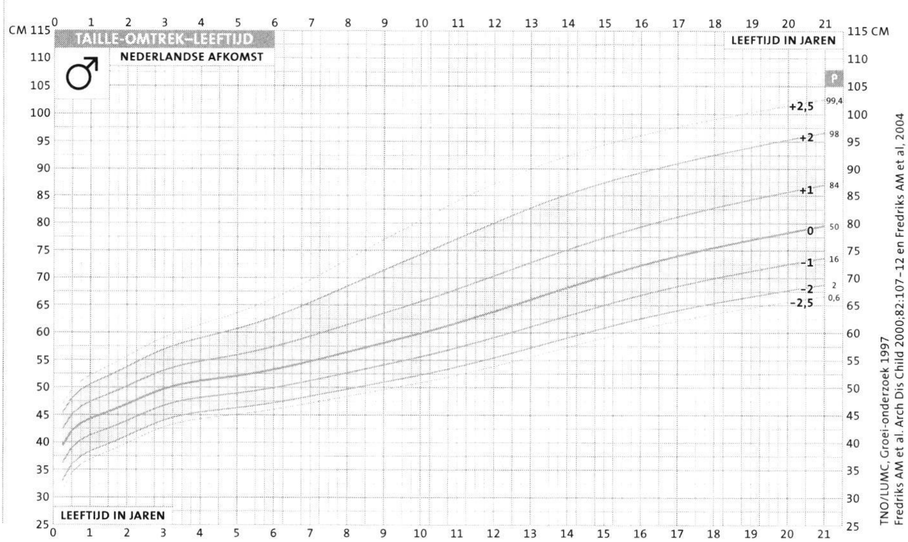
GROEIDIAGRAM 0-21 JAAR | JONGENS NEDERLANDSE AFKOMST

Naam

Geboortedatum | Reg. nr

Vader gew. | kg | BMI | kg/m² | Moeder gew. | kg | BMI | kg/m²





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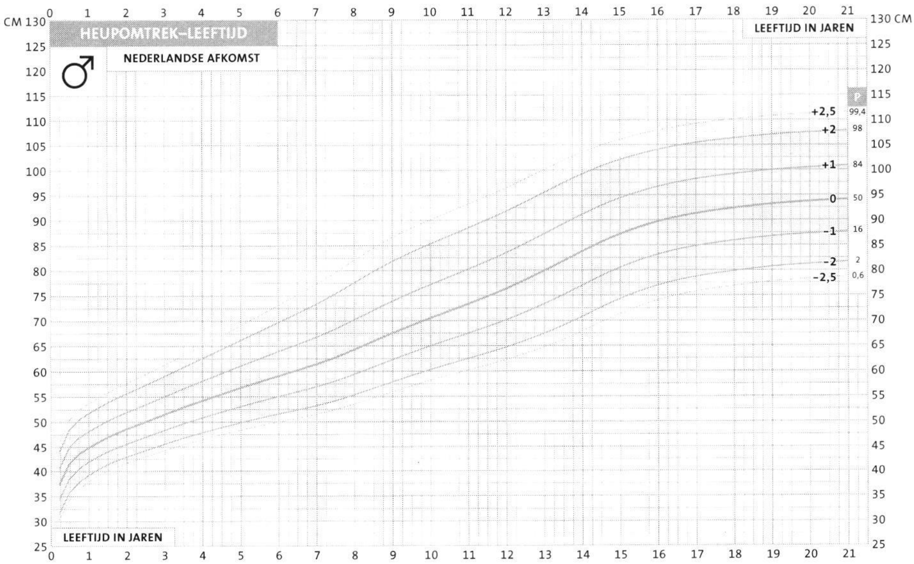
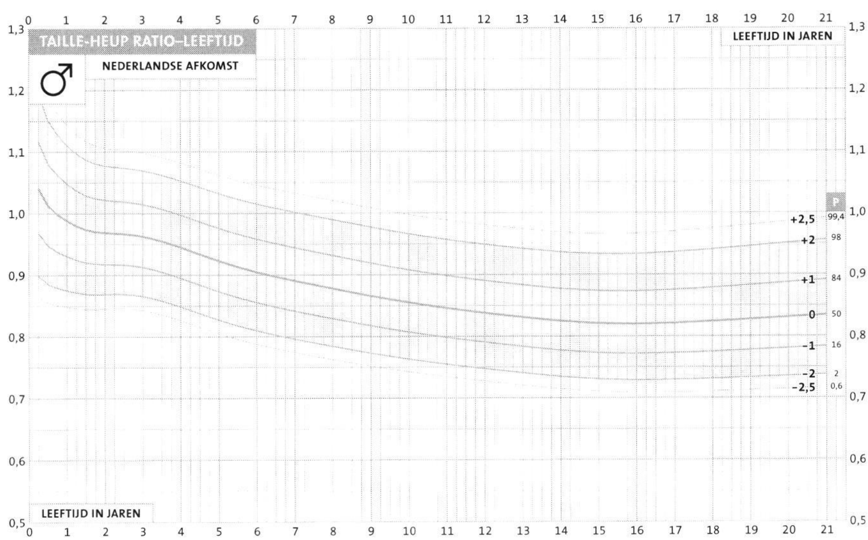
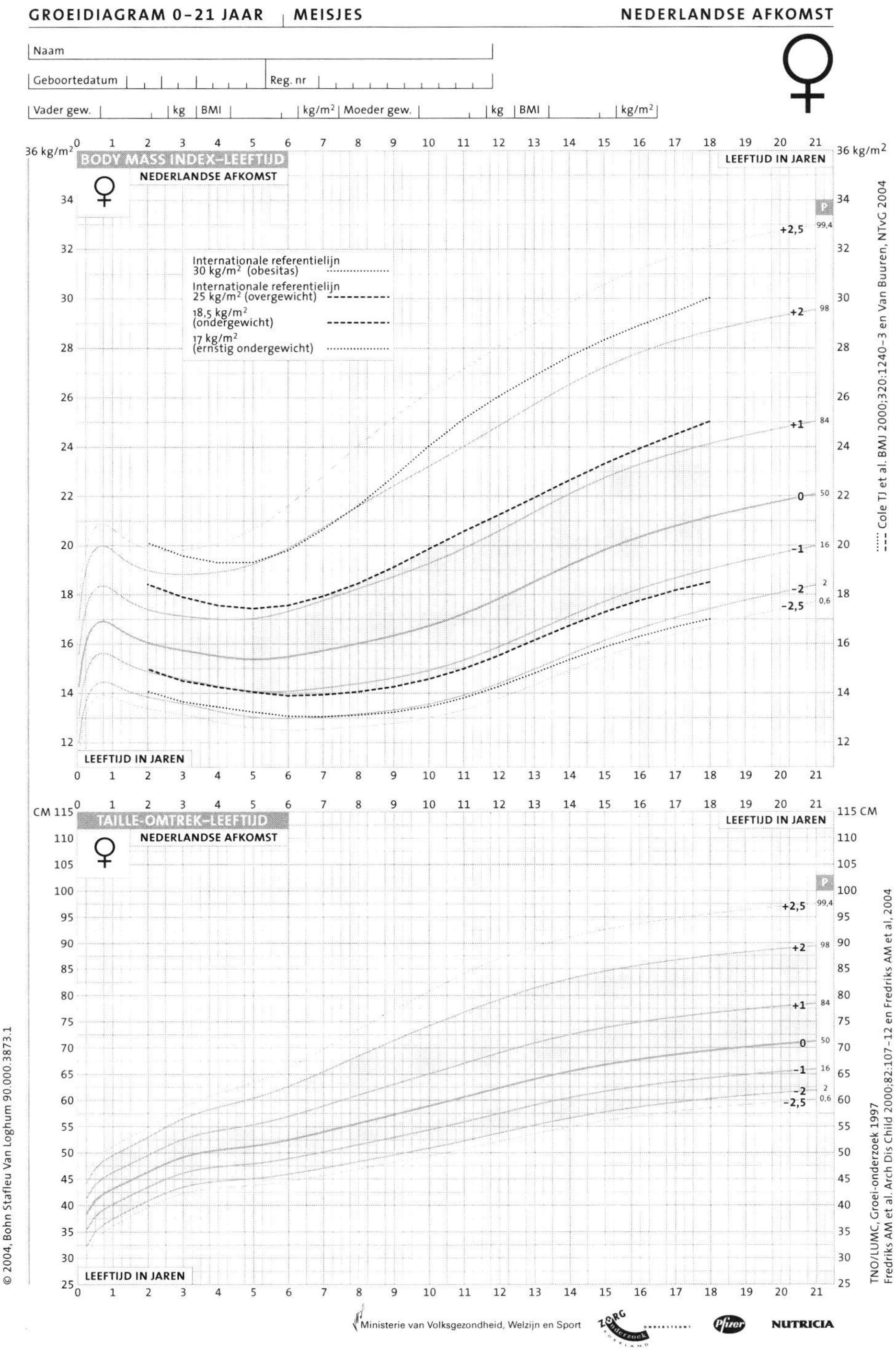




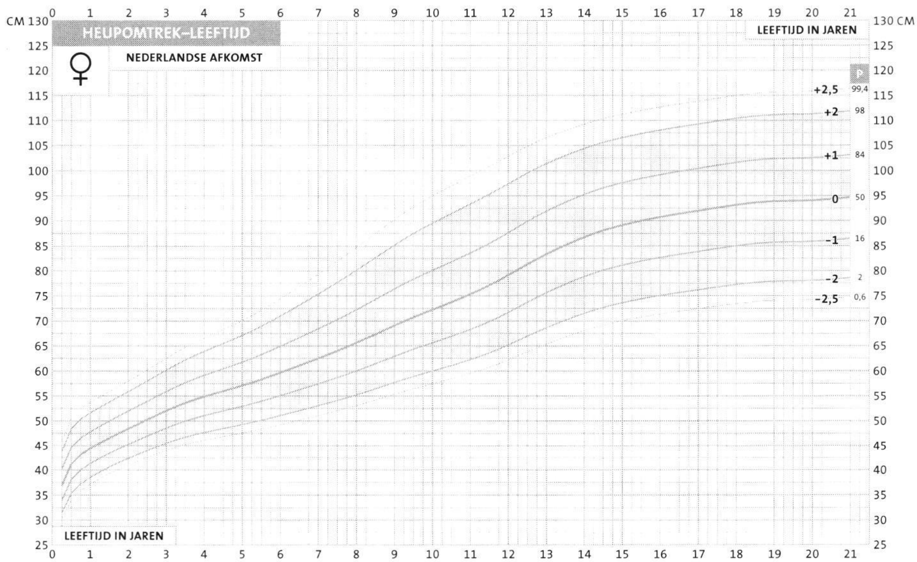
TOELICHTING

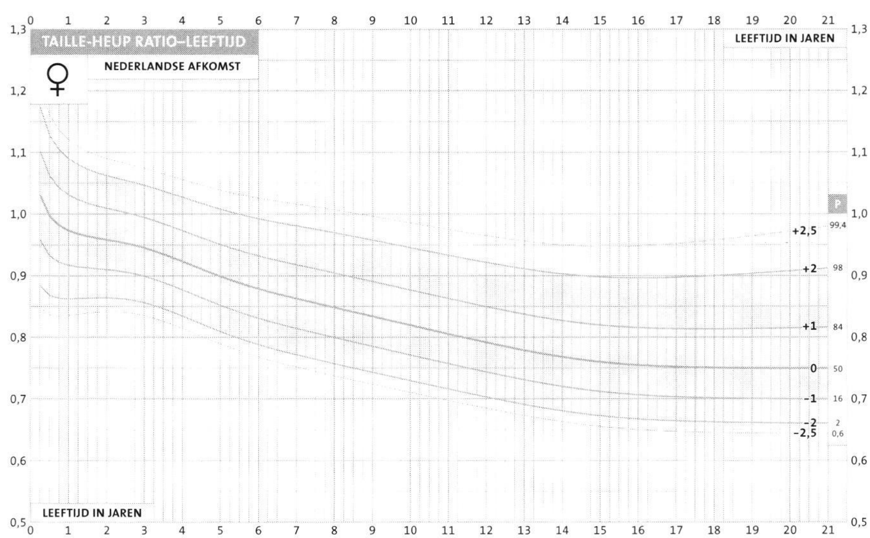
Body mass index (BMI of quetelet-index) wordt berekend door het gewicht (kg) te delen door het kwadraat van de lengte (m^2). BMI is de meest gebruikte maat voor onder- en overgewicht. Als handvat voor het signaleren van overgewicht staan afkaplijnen voor overgewicht en obesitas in de diagrammen weergegeven. Deze zijn verkregen door extrapolatie van de afkappunten bij volwassenen (> 25 kg/m^2 overgewicht, > 30 kg/m^2 obesitas) in zes grote groeistudies, waaronder de Nederlandse 1980 groeistudie (Cole TJ et al BMJ 2000;320:1240-3). Ook voor ondergewicht en ernstig ondergewicht zijn afkaplijnen weergegeven (Van Buuren, NTvG 2004). De taille- en heupomtrek geven een indicatie van de viscerale vetverdeling en het risico op hart- en vaatziekten. Beide worden tot het eerste jaar liggend en daarna staand gemeten. De **taille-omtrek** meet het abdominale vet en wordt gemeten tussen de onderzijde van de ribbenboog en de bovenzijde van de bekkenkam (ongeveer ter hoogte van de navel), aan het eind van een normale uitademing. Bij volwassenen wordt voor mannen een taille-omtrek > 94 cm voor overgewicht aangehouden en een omtrek > 102 cm voor obesitas. Voor vrouwen is dit resp. > 80 cm en > 88 cm. De **heupomtrek** meet het vetweefsel rond de heupen en wordt gemeten ter hoogte van de trochanteres majores.

De **taille/heup ratio** wordt gebruikt als maat voor lichaamsvetverdeling. Bij volwassenen is een ratio > 0.85, "appelvorm", geassocieerd met een hoger risico op cardiovasculaire aandoeningen en mortaliteit dan de "peervorm", met meer vetopslag op de heupen. Bij kinderen is de prognostische betekenis nog niet bekend.



GROEIDIAGRAM 0–21 JAAR
MEISJES
NEDERLANDSE AFKOMST
Naam
Geboortedatum
Reg. nr
Vader gew. kg BMI kg/m²
Moeder gew. kg BMI kg/m²
BODY MASS INDEX–LEEFTIJD
NEDERLANDSE AFKOMST
LEEFTIJD IN JAREN
36 kg/m²
Internationale referentielijn 30 kg/m² (obesitas)
Internationale referentielijn 25 kg/m² (overgewicht)
18,5 kg/m² (ondergewicht)
17 kg/m² (ernstig ondergewicht)
+2,5 +2 +1 0 -1 -2 -2,5
P 99,4 98 84 50 16 2 0,6
Cole TJ et al. BMJ 2000;320:1240-3 en Van Buuren, NTvG 2004
TAILLE-OMTREK–LEEFTIJD
NEDERLANDSE AFKOMST
CM 115
115 CM
LEEFTIJD IN JAREN
© 2004, Bohn Stafleu Van Loghum 90.000.3873.1
TNO/LUMC, Groei-onderzoek 1997
Fredriks AM et al. Arch Dis Child 2000;82:107-12 en Fredriks AM et al, 2004
Ministerie van Volksgezondheid, Welzijn en Sport
NUTRICIA





TOELICHTING

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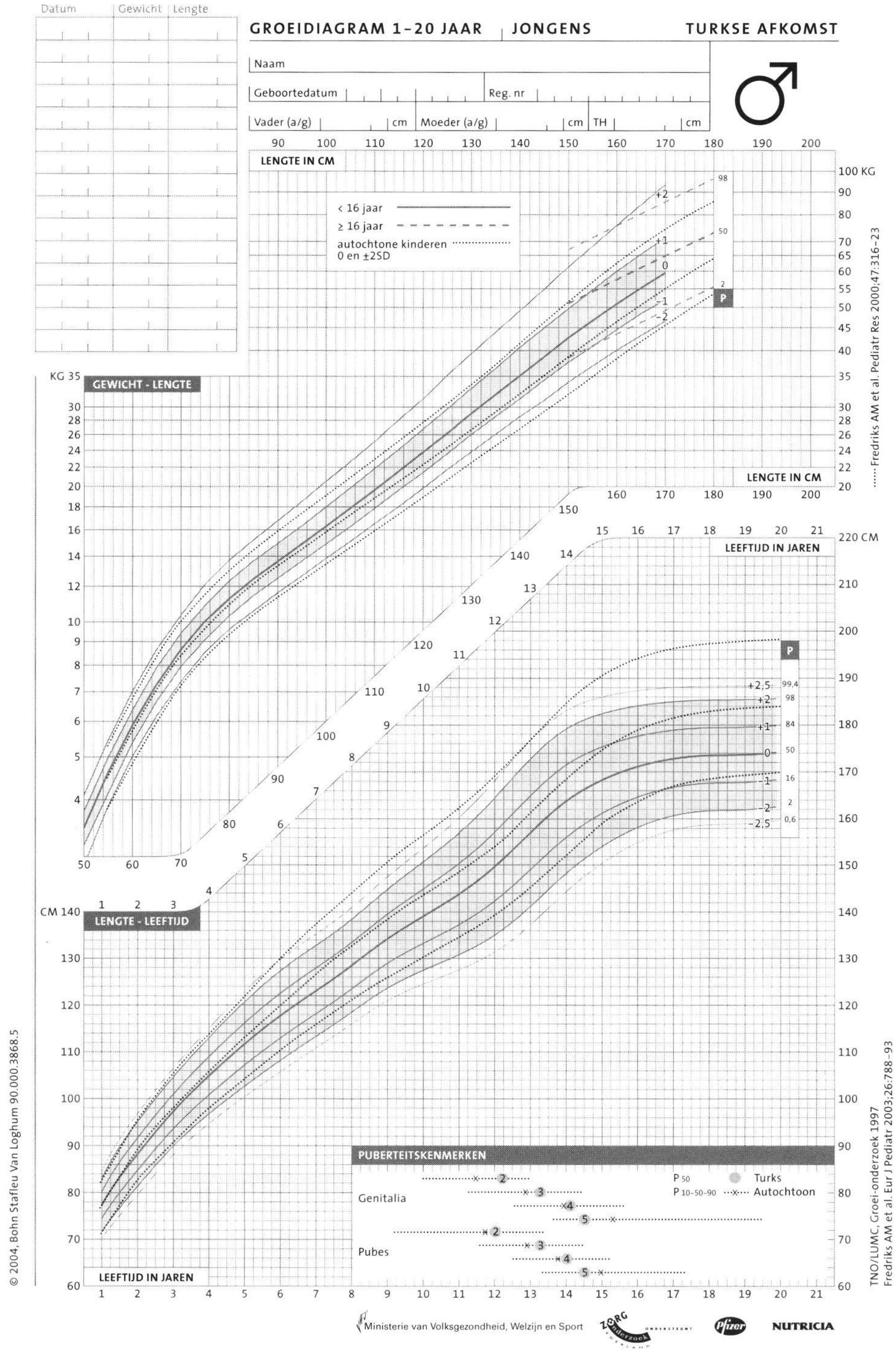
GROEIDIAGRAM 1–20 JAAR
JONGENS
TURKSE AFKOMST
Datum
Gewicht
Lengte
Naam
Geboortedatum
Reg. nr
Vader (a/g)
cm
Moeder (a/g)
TH
LENGTE IN CM
< 16 jaar
≥ 16 jaar
autochtone kinderen
0 en ±2SD
GEWICHT - LENGTE
KG 35
LENGTE IN CM
LEEFTIJD IN JAREN
LENGTE - LEEFTIJD
CM 140
220 CM
100 KG
PUBERTEITSKENMERKEN
Genitalia
Pubes
P 50
P 10-50-90
Turks
Autochtoon
Fredriks AM et al. Pediatr Res 2000;47:316–23
TNO/LUMC, Groei-onderzoek 1997
Fredriks AM et al. Eur J Pediatr 2003;26:788–93
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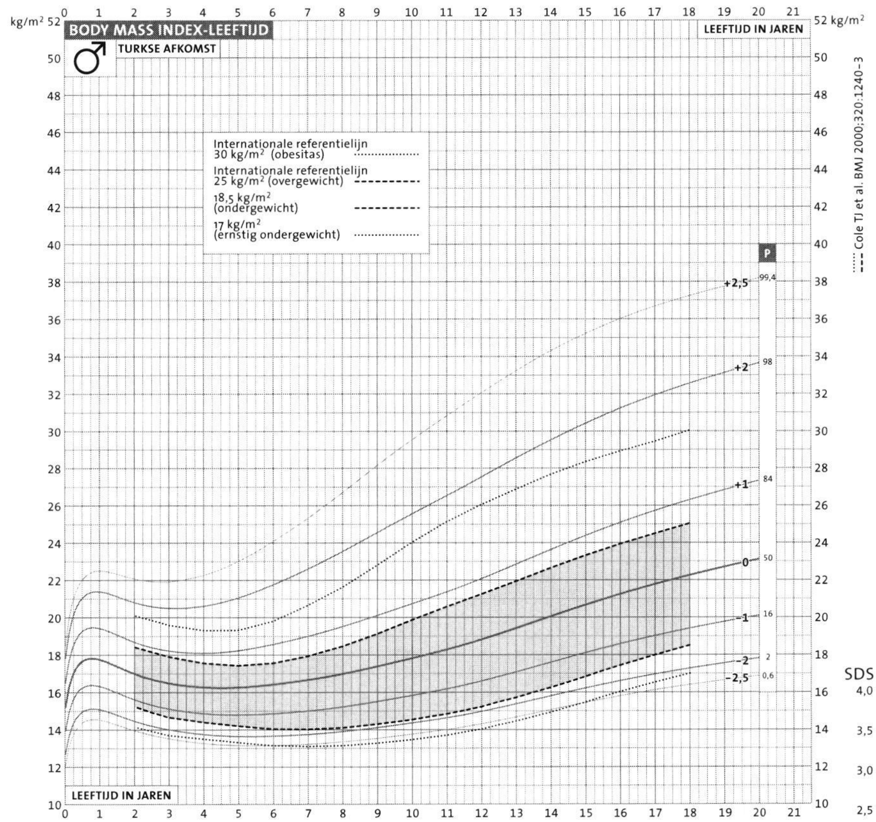
NUTRICIA



TOELICHTING

Body mass index (BMI of quetelet-index) wordt berekend door het gewicht te delen door de lengte². BMI is de meest geschikte maat voor onder- en overgewicht.

De **hoofdomtrek** van allochtone kinderen is vrijwel gelijk aan die in de autochtone hoofdomtrekdiagrammen, zodat deze gebruikt kunnen worden.

De **standaard deviatie** (SD) is een maat voor de spreiding van de meetwaarden rondom het gemiddelde van een populatie, waarbij is aangenomen dat de meetwaarden een normale verdeling hebben: dit geldt bij benadering voor lengte en hoofdomtrek. De **standaard deviatie score** (SDS) is het aantal standaard deviaties boven of onder het gemiddelde. Voor een Turkse jongen (volgens de definitie dat beide ouders uit Turkije afkomstig zijn en dat de jongen in Turkije of Nederland is geboren) kan de lengte-SDS worden berekend op basis van het Turkse lengte-leeftijd diagram of op basis van het Nederlandse diagram. Met de bovenste twee regels uit onderstaande tabel kan de lengte-SDS berekend worden ten opzichte van de eigen referentiegroep.

Wat betreft de **target height** (TH) wordt voor kinderen van niet-Nederlandse afkomst aangeraden om de Nederlandse target height formule te gebruiken. Het man – vrouw lengteverschil voor Turkse volwassenen is eveneens ongeveer 13 cm.
Over het lengteverschil tussen de verschillende generaties bestaan geen gegevens.

In formule:

$$\textbf{TH jongen (cm)} = \frac{\textbf{moederlengte + [vaderlengte + 13]}}{\textbf{2}} + \textbf{4,5}$$

Samengevat:
TH jongen (cm) = gemiddelde ouderlengte + 11

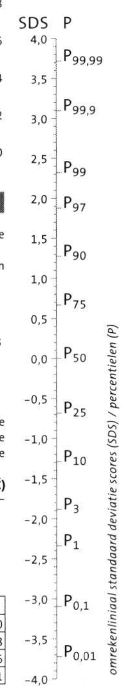
Als men de lengte-SDS wil vergelijken met de TH-SDS, moet zowel de lengte- als de TH-SDS worden uitgedrukt op basis van de Nederlandse referentie. Hiervoor gebruikt men de onderste twee regels uit de tabel. De formules zijn:

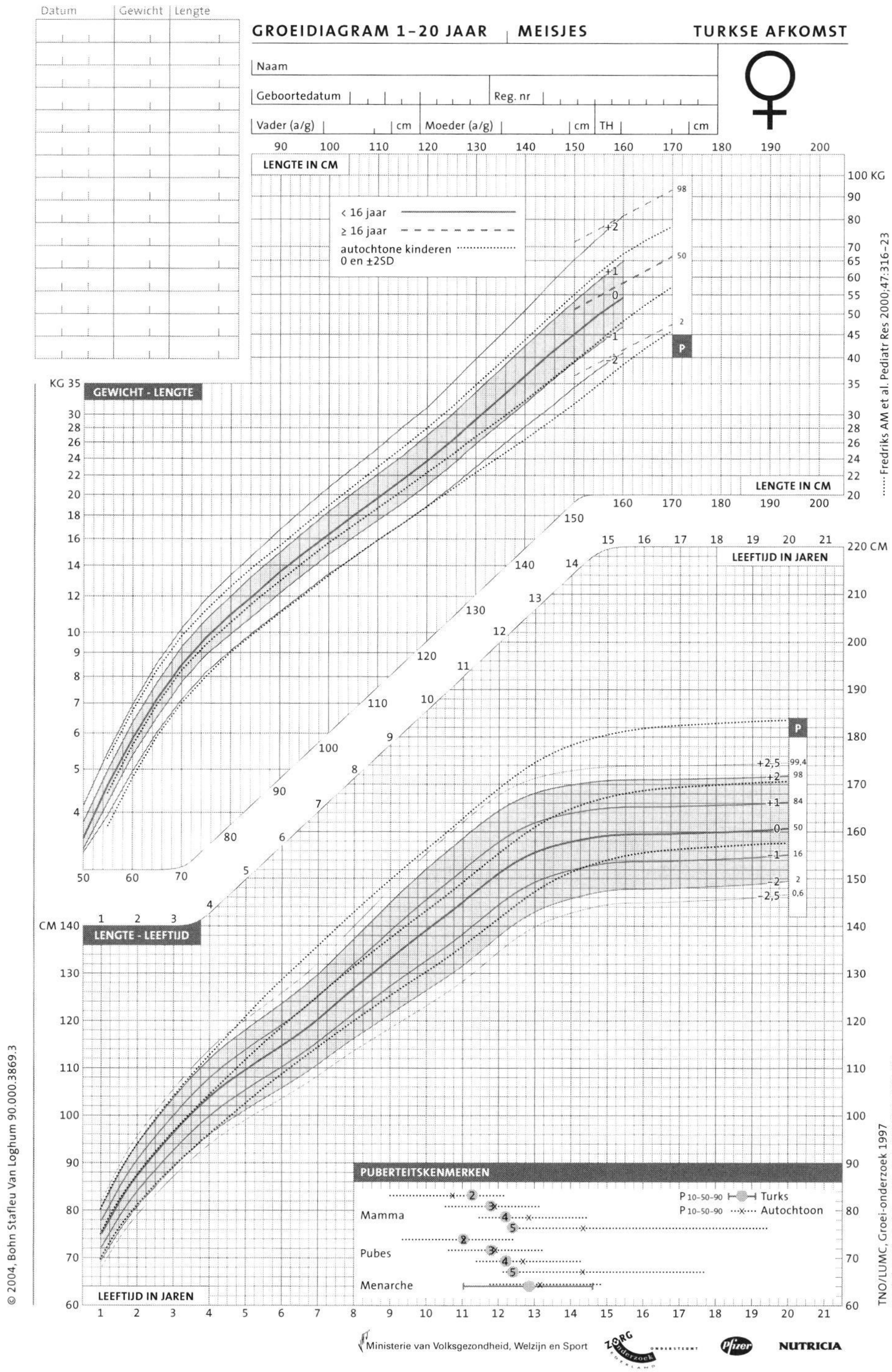
$$\textbf{lengte-SDS} = \frac{\textbf{lengte (cm) – gem. lengte voor leeftijd en geslacht } (\bar{X})}{\textbf{SD voor leeftijd en geslacht}}$$

TH-SDS jongen = (TH – 184,0) / 7,1

♂ Voor de berekening van de lengte-SDS kan de onderstaande tabel gebruikt worden.

Jaar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Turkse $\bar{X}$	77,3	88,0	97,1	104,8	111,5	117,6	122,8	128,1	134,1	138,9	143,4	149,1	156,3	163,4	167,9	170,8	172,5	173,3	173,5	174,0
Turkse SD	2,6	3,3	3,7	4,1	4,5	4,8	4,9	5,0	5,3	5,8	6,5	7,3	7,8	7,7	7,1	6,5	6,1	5,9	5,9	5,8
Autochtone $\bar{X}$	76,6	88,9	98,1	105,8	113,1	120,1	126,6	132,8	138,3	143,2	148,2	154,0	160,9	168,2	174,4	178,7	181,3	182,6	183,2	183,6
Autochtone SD	2,8	3,3	3,7	4,0	4,5	4,9	5,4	5,8	6,2	6,6	7,0	7,5	7,9	8,1	7,9	7,6	7,3	7,2	7,2	7,1




Datum
Gewicht
Lengte
GROEIDIAGRAM 1–20 JAAR
MEISJES
TURKSE AFKOMST
Naam
Geboortedatum
Reg. nr
Vader (a/g)
cm
Moeder (a/g)
cm
TH
cm
LENGTE IN CM
< 16 jaar
≥ 16 jaar
autochtone kinderen
0 en ±2SD
100 KG
GEWICHT - LENGTE
KG 35
LENGTE IN CM
LEEFTIJD IN JAREN
220 CM
CM 140
LENGTE - LEEFTIJD
PUBERTEITSKENMERKEN
Mamma
Pubes
Menarche
P 10-50-90 Turks
P 10-50-90 Autochtoon
LEEFTIJD IN JAREN
Fredriks AM et al. Pediatr Res 2000;47:316–23
TNO/LUMC, Groei-onderzoek 1997
Fredriks AM et al. Eur J Pediatr 2003;26:788–93
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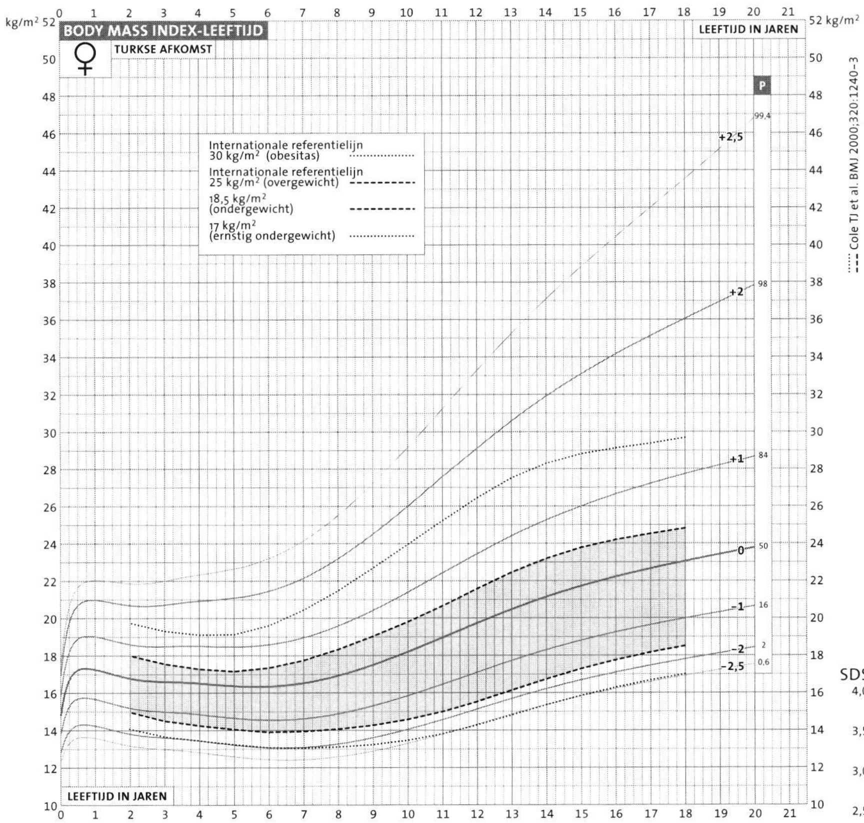
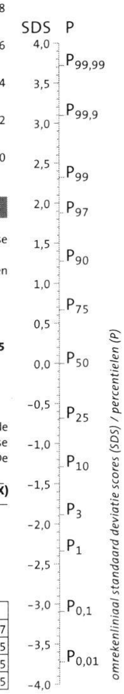




TOELICHTING

Body mass index (BMI of quetelet-index) wordt berekend door het gewicht te delen door de lengte². BMI is de meest geschikte maat voor onder- en overgewicht.

De **hoofdomtrek** van allochtone kinderen is vrijwel gelijk aan die in de autochtone hoofdomtrekdiagrammen, zodat deze gebruikt kunnen worden.

De **standaard deviatie** (SD) is een maat voor de spreiding van de meetwaarden rondom het gemiddelde van een populatie, waarbij is aangenomen dat de meetwaarden een normale verdeling hebben: dit geldt bij benadering voor lengte en hoofdomtrek. De **standaard deviatie score** (SDS) is het aantal standaard deviaties boven of onder het gemiddelde. Voor een Turks meisje (volgens de definitie dat beide ouders uit Turkije afkomstig zijn en dat het meisje in Turkije of Nederland is geboren) kan de lengte-SDS worden berekend op basis van het Turkse lengte-leeftijd diagram of op basis van het Nederlandse diagram. Met de bovenste twee regels uit onderstaande tabel kan de lengte-SDS berekend worden ten opzichte van de eigen referentiegroep.

Wat betreft de **target height** (TH) wordt voor kinderen van niet-Nederlandse afkomst aangeraden om de Nederlandse target height formule te gebruiken. Het man – vrouw lengteverschil voor Turkse volwassenen is eveneens ongeveer 13 cm.
Over het lengteverschil tussen de verschillende generaties bestaan geen gegevens.

In formule:

$$\textbf{TH meisje (cm)} = \frac{\textbf{moederlengte + [vaderlengte - 13]}}{\textbf{2}} + \textbf{4,5}$$

Samengevat:
TH meisje (cm) = gemiddelde ouderlengte - 2

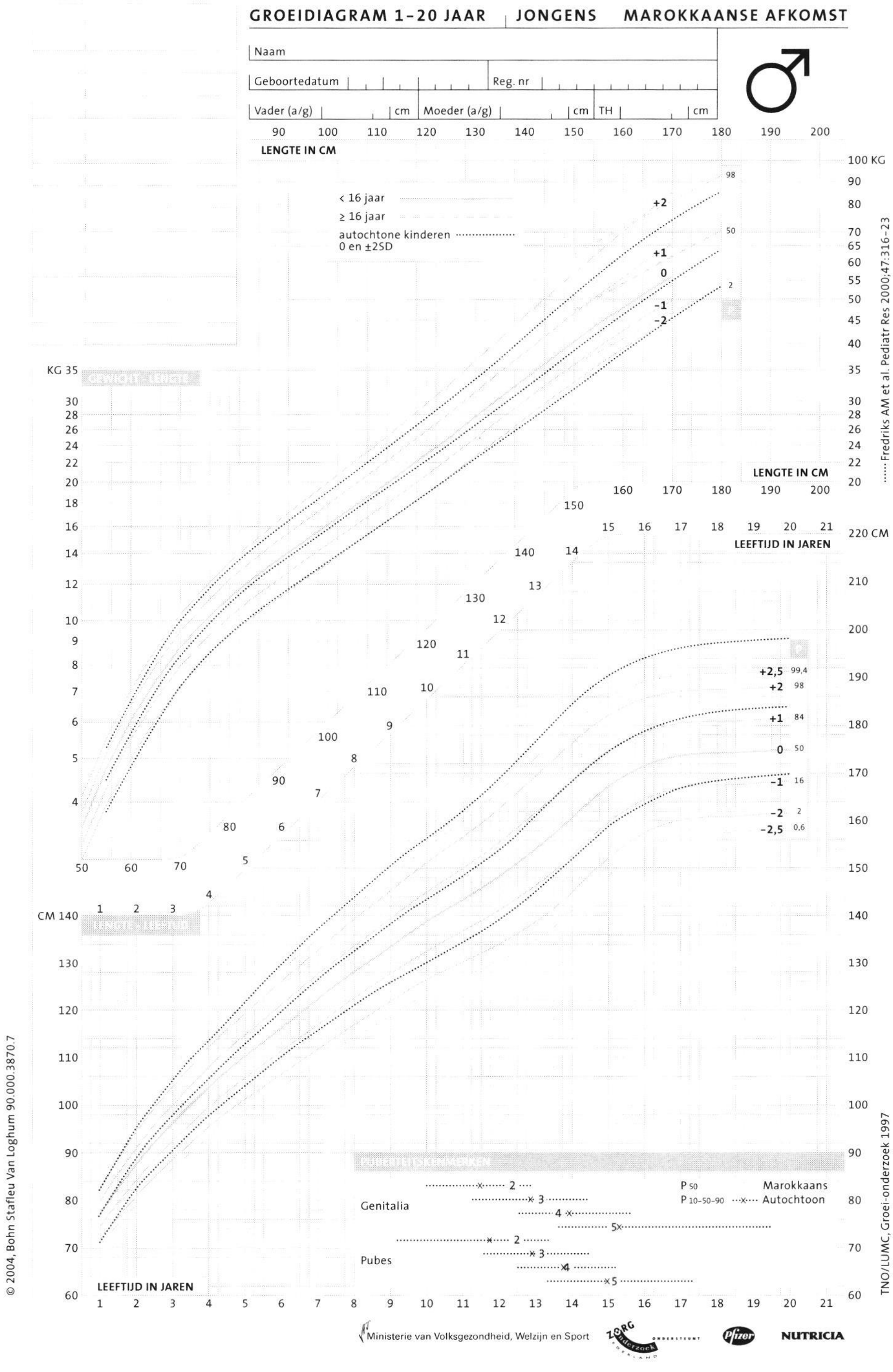
Als men de lengte-SDS wil vergelijken met de TH-SDS, moet zowel de lengte als de TH-SDS worden uitgedrukt op basis van de Nederlandse referentie. Hiervoor gebruikt men de onderste twee regels uit de tabel. De formules zijn:

$$\textbf{lengte-SDS} = \frac{\textbf{lengte (cm) - gem. lengte voor leeftijd en geslacht } (\bar{X})}{\textbf{SD voor leeftijd en geslacht}}$$

TH-SDS meisje = (TH - 170,6) / 6,5

♀ Voor de berekening van de lengte-SDS kan de onderstaande tabel gebruikt worden.

Jaar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Turkse $\bar{X}$	75,2	87,6	96,6	104,1	109,9	114,9	120,6	127,1	133,4	139,5	145,3	151,3	155,7	157,9	159,2	159,5	159,7	159,9	160,2	160,7
Turkse SD	2,8	3,3	3,7	4,0	4,2	4,5	4,8	5,3	5,9	6,4	6,7	6,6	6,3	6,0	5,8	5,8	5,7	5,7	5,6	5,5
Autochtone $\bar{X}$	75,1	87,5	96,7	104,5	111,8	118,7	125,2	131,5	137,5	143,3	149,2	155,3	160,8	164,7	167,1	168,6	169,3	169,8	170,2	170,5
Autochtone SD	2,6	3,2	3,7	4,2	4,6	5,0	5,4	5,8	6,1	6,4	6,7	6,8	6,8	6,7	6,6	6,6	6,5	6,5	6,5	6,5


GROEIDIAGRAM 1–20 JAAR | JONGENS MAROKKAANSE AFKOMST
Naam
Geboortedatum
Reg. nr
Vader (a/g) cm
Moeder (a/g) cm
TH cm
LENGTE IN CM
< 16 jaar
≥ 16 jaar
autochtone kinderen
0 en ±2SD
GEWICHT - LENGTE
KG 35
100 KG
LENGTE IN CM
LEEFTIJD IN JAREN
220 CM
LENGTE - LEEFTIJD
CM 140
PUBERTEITSKENMERKEN
Genitalia
Pubes
P 50 Marokkaans
P 10-50-90 Autochtoon
LEEFTIJD IN JAREN
Fredriks AM et al. Pediatr Res 2000;47:316–23
TNO/LUMC, Groei-onderzoek 1997
Fredriks AM et al. Acta Paediatr 2004
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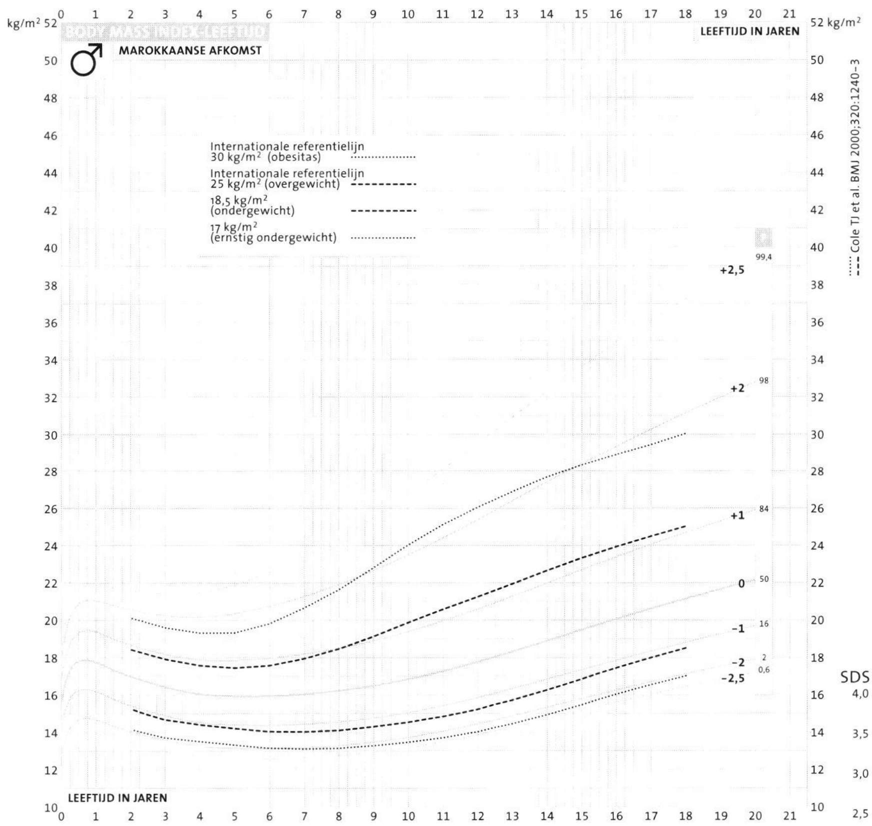
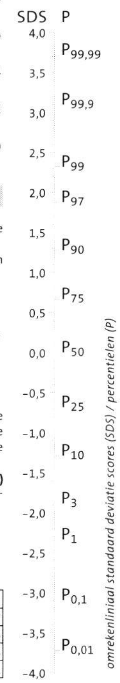




TOELICHTING

Body mass index (BMI of quetelet-index) wordt berekend door het gewicht te delen door de lengte^2. BMI is de meest geschikte maat voor onder- en overgewicht.

De **hoofdomtrek** van allochtone kinderen is vrijwel gelijk aan die in de autochtone hoofdomtrekdiagrammen, zodat deze gebruikt kunnen worden.

De **standaard deviatie** (SD) is een maat voor de spreiding van de meetwaarden rondom het gemiddelde van een populatie, waarbij is aangenomen dat de meetwaarden een normale verdeling hebben: dit geldt bij benadering voor lengte en hoofdomtrek. De **standaard deviatie score** (SDS) is het aantal standaard deviaties boven of onder het gemiddelde. Voor een Marokkaanse jongen (volgens de definitie dat beide ouders uit Marokko afkomstig zijn en dat de jongen in Marokko of Nederland is geboren) kan de lengte-SDS worden berekend op basis van het Marokkaanse lengte-leeftijd diagram of op basis van het Nederlandse diagram. Met de bovenste twee regels uit onderstaande tabel kan de lengte-SDS berekend worden ten opzichte van de eigen referentiegroep.

Wat betreft de **target height** (TH) wordt voor kinderen van niet-Nederlandse afkomst aangeraden om de Nederlandse target height formule te gebruiken. Het man – vrouw lengteverschil voor Marokkaanse volwassenen is eveneens ongeveer 13 cm.
Over het lengteverschil tussen de verschillende generaties bestaan geen gegevens.

In formule:

$$\textbf{TH jongen (cm)} = \frac{\textbf{moederlengte + [vaderlengte + 13]}}{\textbf{2}} + \textbf{4,5}$$

Samengevat:
TH jongen (cm) = gemiddelde ouderlengte + 11

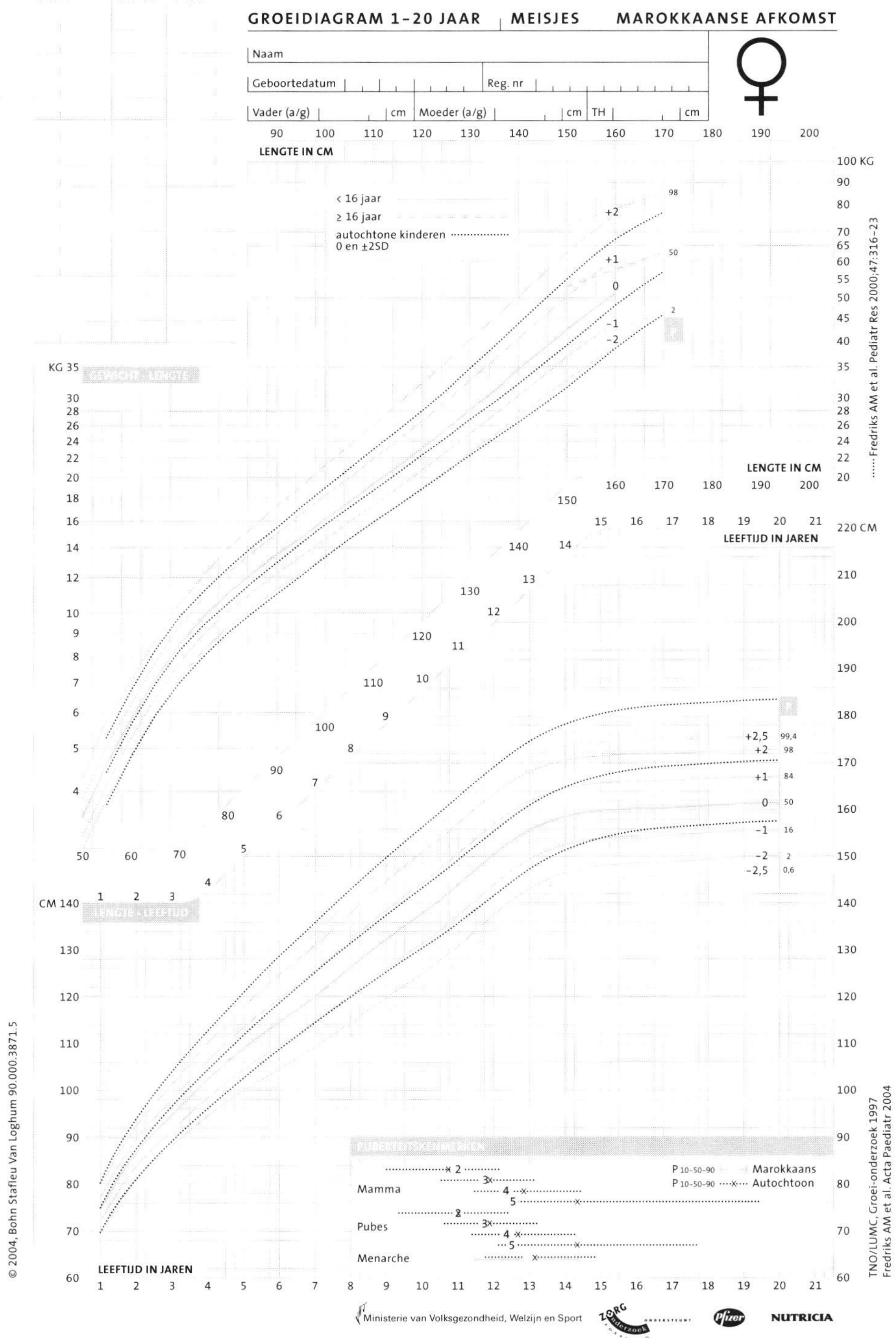
Als men de lengte-SDS wil vergelijken met de TH-SDS, moet zowel de lengte- als de TH-SDS worden uitgedrukt op basis van de Nederlandse referentie. Hiervoor gebruikt men de onderste twee regels uit de tabel. De formules zijn:

$$\textbf{lengte-SDS} = \frac{\textbf{lengte (cm) – gem. lengte voor leeftijd en geslacht } (\bar{X})}{\textbf{SD voor leeftijd en geslacht}}$$

TH-SDS jongen = (TH – 184,0) / 7,1

♂ Voor de berekening van de lengte-SDS kan de onderstaande tabel gebruikt worden.

Jaar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Marokkaanse $\bar{X}$	77,2	87,7	96,3	103,8	110,3	116,2	122,2	128,0	133,4	138,7	143,3	148,1	153,8	160,3	166,8	171,2	173,5	174,0	174,3	174,7
Marokkaanse SD	2,6	3,4	3,8	4,2	4,5	4,9	5,3	5,6	5,9	6,2	6,6	7,1	7,6	7,8	7,5	7,0	6,8	6,7	6,6	6,6
Autochtone $\bar{X}$	76,6	88,9	98,1	105,8	113,1	120,1	126,6	132,8	138,3	143,2	148,2	154,0	160,9	168,2	174,4	178,7	181,3	182,6	183,2	183,6
Autochtone SD	2,8	3,3	3,7	4,0	4,5	4,9	5,4	5,8	6,2	6,6	7,0	7,5	7,9	8,1	7,9	7,6	7,3	7,2	7,2	7,1


GROEIDIAGRAM 1-20 JAAR | MEISJES MAROKKAANSE AFKOMST
Naam
Geboortedatum
Reg. nr
Vader (a/g) cm
Moeder (a/g) cm
TH cm
LENGTE IN CM
< 16 jaar
≥ 16 jaar
autochtone kinderen 0 en ±2SD
GEWICHT - LENGTE
KG
LENGTE IN CM
LEEFTIJD IN JAREN
LENGTE - LEEFTIJD
CM
PUBERTEITSKENMERKEN
Mamma
Pubes
Menarche
P 10-50-90 Marokkaans
P 10-50-90 Autochtoon
LEEFTIJD IN JAREN
Fredriks AM et al. Pediatr Res 2000;47:316-23
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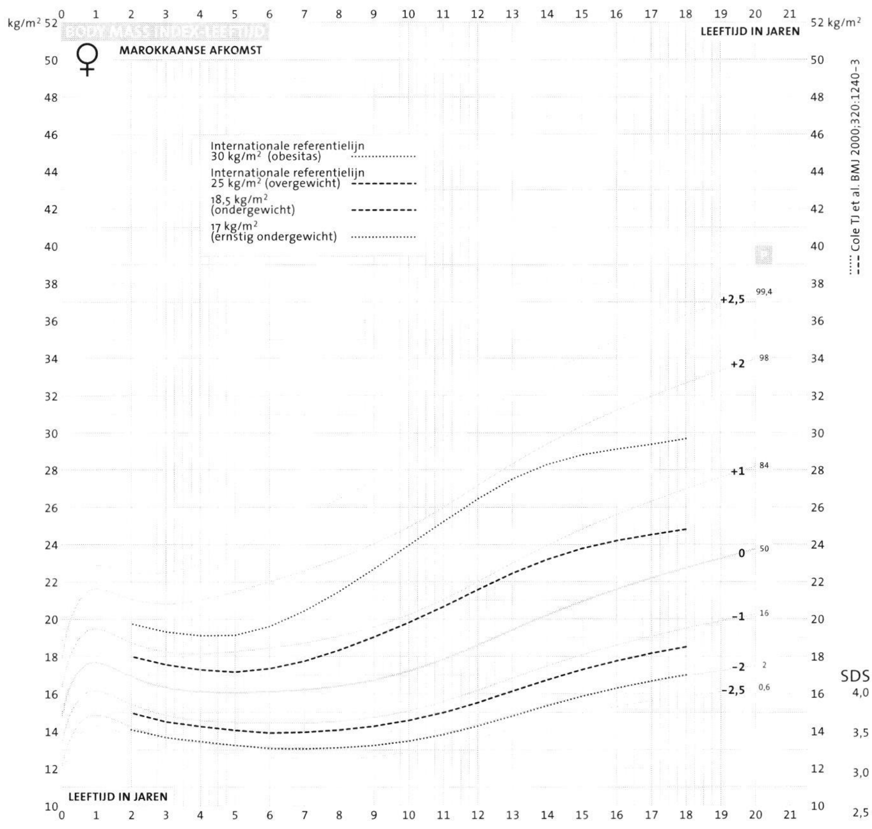

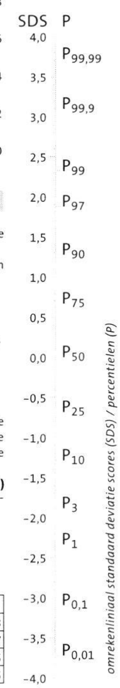

TOELICHTING

Body mass index (BMI of quetelet-index) wordt berekend door het gewicht te delen door de lengte². BMI is de meest geschikte maat voor onder- en overgewicht.

De **hoofdomtrek** van allochtone kinderen is vrijwel gelijk aan die in de autochtone hoofdomtrekdiagrammen, zodat deze gebruikt kunnen worden.

De **standaard deviatie** (SD) is een maat voor de spreiding van de meetwaarden rondom het gemiddelde van een populatie, waarbij is aangenomen dat de meetwaarden een normale verdeling hebben: dit geldt bij benadering voor lengte en hoofdomtrek. De **standaard deviatie score** (SDS) is het aantal standaard deviaties boven of onder het gemiddelde. Voor een Marokkaans meisje (volgens de definitie dat beide ouders uit Marokko afkomstig zijn en dat het meisje in Marokko of Nederland is geboren) kan de lengte-SDS worden berekend op basis van het Marokkaanse lengte-leeftijd diagram of op basis van het Nederlandse diagram. Met de bovenste twee regels uit onderstaande tabel kan de lengte-SDS berekend worden ten opzichte van de eigen referentiegroep.

Wat betreft de **target height** (TH) wordt voor kinderen van niet-Nederlandse afkomst aangeraden om de Nederlandse target height formule te gebruiken. Het man – vrouw lengteverschil voor Marokkaanse volwassenen is eveneens ongeveer 13 cm.
Over het lengteverschil tussen de verschillende generaties bestaan geen gegevens.

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Samengevat:
TH meisje (cm) = gemiddelde ouderlengte - 2

Als men de lengte-SDS wil vergelijken met de TH-SDS, moet zowel de lengte- als de TH-SDS worden uitgedrukt op basis van de Nederlandse referentie. Hiervoor gebruikt men de onderste twee regels uit de tabel. De formules zijn:

$$\textbf{lengte-SDS} = \frac{\text{lengte (cm)} - \text{gem. lengte voor leeftijd en geslacht } (\bar{X})}{\text{SD voor leeftijd en geslacht}}$$

TH-SDS meisje = (TH - 170,6) / 6,5

♀ Voor de berekening van de lengte-SDS kan de onderstaande tabel gebruikt worden.

Jaar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Marokkaanse $\bar{X}$	74,9	86,8	94,8	102,4	109,0	114,6	120,2	126,4	132,4	138,0	144,0	150,5	155,7	158,6	159,8	160,3	160,4	160,9	161,3	161,3
Marokkaanse SD	2,6	2,9	3,3	3,9	4,5	5,0	5,5	5,9	6,3	6,5	6,6	6,5	6,2	6,0	5,9	5,8	5,8	5,7	5,7	5,7
Autochtone $\bar{X}$	75,1	87,5	96,7	104,5	111,8	118,7	125,2	131,5	137,5	143,3	149,2	155,3	160,8	164,7	167,1	168,6	169,3	169,8	170,2	170,5
Autochtone SD	2,6	3,2	3,7	4,2	4,6	5,0	5,4	5,8	6,1	6,4	6,7	6,8	6,8	6,7	6,6	6,6	6,5	6,5	6,5	6,5

Curriculum

Vitae

Curriculum Vitae

The author of this thesis was born on August 2nd, 1969 in Apeldoorn, the Netherlands. She attended secondary school in Ede, 'Chr. Streeklyceum', and passed her exam in 1987. The following year she followed physics and science courses at the Free University in Amsterdam. From 1988 to 1995, she studied Medicine at the Free University in Amsterdam. During these years she participated in a study at the department of Paediatrics about the influence of intranasal steroids on bronchial responsiveness in children with asthma and hay fever (head: dr. J.E. Dankert-Roelse). She was also a board member of the NEMSIC and organized international research exchanges for students. She participated for two months in a general practitioner clinic at Lewis Island, Scotland. For a short period she worked as medical doctor in a Well Baby Clinic in Amsterdam. From January 1996 until 1997, she worked as MD in the Department of Paediatrics in the Diaconessen Hospital in Leiden. From February 1997, the studies presented in this thesis were conducted at the Division Child Health of TNO Prevention and Health in Leiden (Head: Prof. Dr. S.P. Verloove-Vanhorick), in close collaboration with the Department of Pediatric in Leiden University Medical Center in Leiden (Head: Prof. Dr. J.M. Wit). In June 1998, the first results of this research were presented at a symposium in the Congress Center in The Hague. Besides the analysis of the growth data, she instructed and taught nurses and doctors in child health care how to measure and to use the new growth charts. She wrote an instruction book for nurses and doctors in youth health care and paediatrics. From March 2002, she followed the training for paediatrician at the Leiden University Medical Center. Since September 2003, she started her specialization into Psychiatry, in the University Medical Center in Utrecht (Head: Prof. Dr. R.S. Kahn).

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