Continuing Positive Secular Growth Change in the Netherlands 1955–1997

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ABSTRACT

Since 1858, an increase of mean stature has been observed in the Netherlands, reflecting the improving nutritional, hygienic, and health status of the population. In this study, stature, weight, and pubertal development of Dutch youth, derived from four consecutive nationwide cross-sectional growth studies during the past 42 y, are compared to assess the size and rate of the secular growth change. 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. 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 y. Environmental conditions have been favorable 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, and hygiene, and a reduction of family size. (*Pediatr Res* **47: 316–323, 2000**)

Abbreviations
SDS, standard deviation score
LMS, the data distribution is summarized by the L, M, and S curves
QQ plot, quantile–quantile plot
G, genital development
PH, pubic hair
B, breast development
M, menarche
P_{10}, P_{50}, P_{90}, 10th, 50th, and 90th percentile

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 biologic 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 favorable environmental conditions have to be around, before the maximum biologic 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 nonrandom samples from the population. In 1955, 1965, and 1980, however, large cross-sectional nationwide 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 circum-

ference, and secondary sex characteristics from the fourth nationwide growth study in 1997, using a methodology similar to the previous studies, and compare the results of all four nationwide growth studies, to assess whether any further secular growth change has occurred.

METHODS

Subjects. Data collection for the first nationwide 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 birth weight <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 nationwide 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 on the basis of 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 y 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 and 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 2 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 millimeters. 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 PH (7). Testicular volume was estimated by means of a Prader orchidometer. The age at M 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 socioeconomic 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 trans-

formation power that converts y to normality and minimizes the skewness of the data set (L), the median (M), and the coefficient of variation (S). In the LMS model, the smoothness of L, M, and S curves is characterized by the number of effective degrees of freedom. The choice of these smoothing factors for the L, M, and S curves was made by creating local detrended QQ 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 factors 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 modeling 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 mo. 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).

Height and weight for age. Table 1 summarizes the mean and SD 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 mo 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 y 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.

Comparison of mean heights between the sample according to the exclusion criteria of previous studies (which excluded children with a birth weight <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 y 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 stud-

ies. Thus, height references would slightly increase if the previous criteria had been used.

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 1 y 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 during the past 32 y. 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 y for boys and girls amounted to 184.0 cm and 170.6 cm, respectively. During the last 42 y, 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 with 13.7, 11.7, and 13.0 in the 1980, 1965, and 1955 studies (average difference, 13 cm).

Weight for height. Table 2 contains the actual 0 SD and ± 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).

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), socioeconomic status (children with higher socioeconomic status 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 ($\geq 200\,000$ 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.

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 | | | | | | | Girls | | | | | | |
| | Length/ Height (cm) (n = 7447) | | Weight (kg) (n = 7465) | | | Head (cm) (n = 7037) | | Length/ Height (cm) (n = 6992) | | Weight (kg) (n = 6994) | | | Head (cm) (n = 6450) | |
Age	Mean	SD	−2 SD	0 SD	+2 SD	Mean	SD	Mean	SD	−2 SD	0 SD	+2 SD	Mean	SD
2.0 wk	52.9	2.1	3.1	3.9	4.9	36.5	1.4	52.3	2.0	2.9	3.7	4.6	35.8	1.3
4.0 wk	54.5	2.2	3.4	4.3	5.4	37.4	1.4	53.6	2.0	3.2	4.1	5.1	36.6	1.3
6.0 wk	56.1	2.2	3.7	4.7	5.9	38.3	1.4	55.0	2.1	3.5	4.4	5.5	37.4	1.3
8.0 wk	57.6	2.3	4.0	5.1	6.3	39.2	1.4	56.4	2.1	3.8	4.8	5.9	38.2	1.3
10.0 wk	59.1	2.3	4.3	5.5	6.8	39.9	1.4	57.7	2.1	4.0	5.1	6.3	38.9	1.3
12.0 wk	60.5	2.3	4.6	5.8	7.2	40.6	1.4	59.0	2.2	4.3	5.4	6.8	39.5	1.3
14.0 wk	61.8	2.4	4.9	6.2	7.7	41.2	1.4	60.2	2.2	4.6	5.7	7.1	40.1	1.3
16.0 wk	63.0	2.4	5.1	6.5	8.1	41.8	1.4	61.4	2.2	4.8	6.0	7.5	40.7	1.3
18.0 wk	64.2	2.4	5.4	6.8	8.5	42.3	1.3	62.5	2.3	5.0	6.3	7.9	41.2	1.3
20.0 wk	65.2	2.4	5.6	7.1	8.8	42.8	1.4	63.6	2.3	5.3	6.6	8.2	41.7	1.3
22.0 wk	66.2	2.5	5.8	7.4	9.2	43.3	1.4	64.6	2.3	5.5	6.9	8.5	42.1	1.3
24.0 wk	67.1	2.5	6.0	7.6	9.5	43.7	1.4	65.5	2.3	5.7	7.1	8.8	42.5	1.3
26.0 wk	67.9	2.5	6.2	7.9	9.8	44.1	1.4	66.4	2.4	5.9	7.3	9.1	42.9	1.3
28.0 wk	68.8	2.5	6.4	8.1	10.1	44.5	1.4	67.2	2.4	6.0	7.7	9.4	43.2	1.3
32.0 wk	70.3	2.6	6.8	8.5	10.6	45.1	1.4	68.7	2.4	6.4	8.0	9.9	43.8	1.3
36.0 wk	71.6	2.6	7.1	8.9	11.1	45.6	1.4	70.1	2.5	6.7	8.3	10.3	44.3	1.4
40.0 wk	72.9	2.6	7.4	9.3	11.6	46.1	1.4	71.4	2.5	7.0	8.7	10.8	44.7	1.4
44.0 wk	74.2	2.7	7.6	9.6	12.0	46.5	1.4	72.7	2.6	7.2	9.0	11.2	45.2	1.4
48.0 wk	75.4	2.7	7.9	9.9	12.4	46.8	1.5	73.9	2.6	7.4	9.3	11.5	45.5	1.4
52.0 wk	76.5	2.8	8.1	10.2	12.7	47.2	1.5	75.1	2.6	7.7	9.5	11.9	45.9	1.4
56.0 wk	77.6	2.8	8.3	10.5	13.1	47.4	1.5	76.3	2.7	7.9	9.8	12.2	46.1	1.4
60.0 wk	78.7	2.8	8.5	10.7	13.4	47.7	1.5	77.4	2.7	8.1	10.1	12.5	46.4	1.4
1.0 y	76.6	2.8	8.1	10.2	12.8	47.2	1.5	75.1	2.6	7.7	9.6	11.9	45.9	1.4
2.0 y	88.9	3.3	10.4	13.0	16.4	49.3	1.6	87.5	3.2	9.9	12.3	15.5	48.1	1.5
3.0 y	98.1	3.3	12.1	15.2	19.3	50.6	1.7	96.7	3.7	11.7	14.7	18.7	49.3	1.6
4.0 y	105.8	4.0	13.8	17.4	22.4	51.2	1.7	104.5	4.2	13.4	16.9	22.0	50.1	1.6
5.0 y	113.1	4.5	15.5	19.8	25.9	51.5	1.7	111.8	4.6	15.0	19.2	25.5	50.6	1.6
6.0 y	120.1	4.9	17.4	22.4	29.8	51.7	1.7	118.7	5.0	16.8	21.8	29.6	50.9	1.7
7.0 y	126.6	5.4	19.3	25.0	34.0	52.0	1.7	125.2	5.4	18.8	24.7	34.5	51.2	1.6
8.0 y	132.8	5.8	21.2	27.9	38.6	52.5	1.7	131.5	5.6	20.8	27.8	40.1	51.7	1.7
9.0 y	138.3	6.2	23.2	30.8	43.5	52.9	1.7	137.5	6.1	22.8	31.0	46.0	52.2	1.7
10.0 y	143.2	6.6	25.2	33.8	48.6	53.3	1.7	143.3	6.4	24.9	34.5	52.2	52.7	1.7
11.0 y	148.2	7.0	27.4	37.2	54.3	53.7	1.7	149.2	6.7	27.3	38.5	58.8	53.3	1.7
12.0 y	154.0	7.5	30.0	41.5	60.8	54.1	1.7	155.3	6.8	30.4	43.2	65.4	53.8	1.7
13.0 y	160.9	7.9	33.3	46.8	68.3	54.6	1.7	160.8	6.8	34.6	48.3	70.8	54.3	1.7
14.0 y	168.2	8.1	37.6	52.9	76.1	55.3	1.7	164.7	6.7	38.9	52.7	74.7	54.7	1.7
15.0 y	174.4	7.9	42.5	58.8	82.8	55.9	1.7	167.1	6.6	42.4	56.0	77.7	54.9	1.7
16.0 y	178.7	7.6	47.0	63.8	87.7	56.4	1.8	168.6	6.6	45.0	58.4	80.3	55.1	1.7
17.0 y	181.3	7.3	50.7	67.4	91.1	56.8	1.8	169.3	6.5	46.8	60.0	82.3	55.2	1.7
18.0 y	182.6	7.2	53.4	70.1	93.4	57.1	1.8	169.8	6.5	48.1	61.3	83.8	55.3	1.7
19.0 y	183.2	7.2	55.4	72.0	95.1	57.3	1.8	170.2	6.5	49.1	62.3	85.1	55.3	1.7
20.0 y	183.6	7.1	57.2	73.7	96.5	57.6	1.8	170.5	6.5	50.0	63.1	86.1	55.3	1.7
21.0 y	184.0	7.1	58.9	75.3	97.7	57.8	1.8	170.6	6.5	50.8	63.9	87.1	55.3	1.7

Sexual maturation. The P_{10}, P_{50}, and P_{90} ages at attaining pubertal stages (G, PH, and testicular volume for boys, and B, PH, and M for girls) in the 1997 study are shown in Table 3. In 1997, girls developed stages B2 and B3 2 mo later than in 1980, but 2–3 mo earlier than in 1965. However, the median age at B4 and B5 was virtually identical to 1980, both being 6–12 mo lower than in 1965. The 3-mo 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 y in 1980 and 1997, respectively (1 mo/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 y, but the median age at G3-G4 has remained similar. The 2-mo decrease of the mean interval between G2 and G4 and between PH2 and PH4 since 1980 was not statistically significant ($p = 0.20$, two-sided).

DISCUSSION

Comparison of the results of the fourth nationwide growth study with those of the three previous studies shows that during a period of 42 y, the mean height of Dutch children, adolescents, and young adults, in 1980 already among the tallest on earth, has further increased during the past 17 y. At present, the
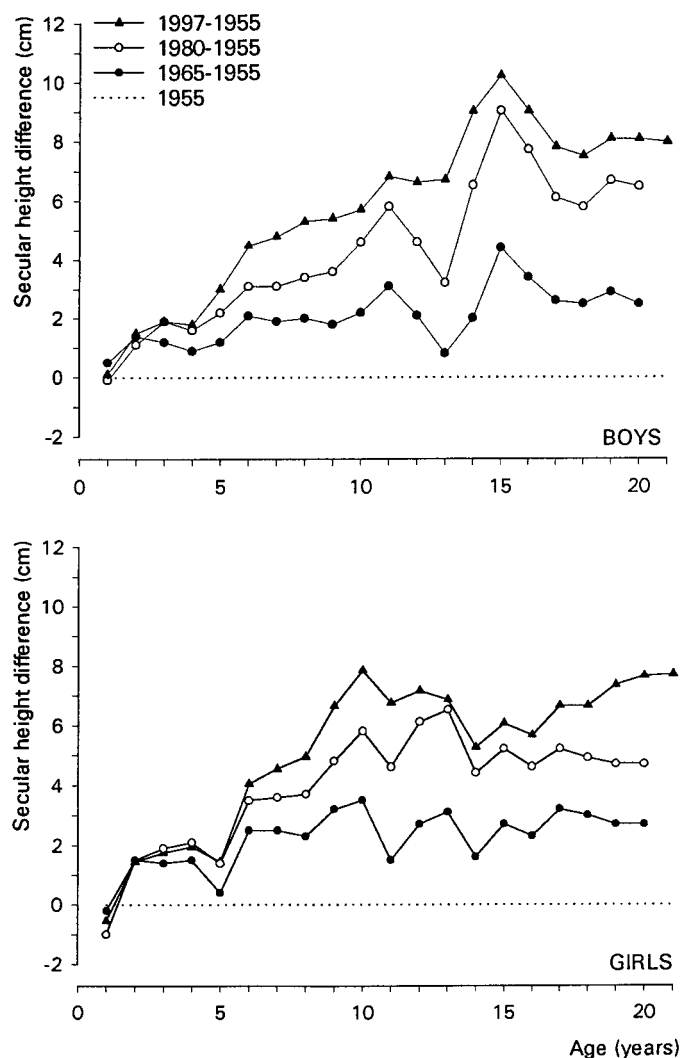
Figure 1. Secular differences in mean height between the 1997, 1980, and 1965 growth studies in comparison to data from the 1955 growth study.
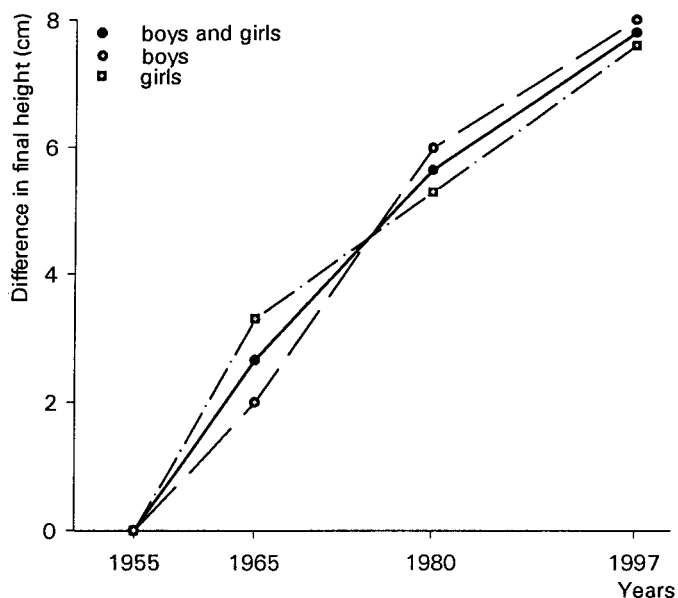

Figure 2. Final height (cm) in the 1965, 1980, and 1997 growth studies relative to the 1955 growth study for boys and girls and their average.

median age at stage G2 tended to increase during the past 30 y, although the mean interval between successive stages tended to decrease. In girls, a progressive shift in median age at M slowly decreased during the past four decades, but, the shift during the past 32 y 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 y, 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 during 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

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 y (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 y (17).

The secular change during the last 42 y varies at different ages, with virtually no change in the first year, very little change until 4–5 y, and a major change from 5 to 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 y of age remained very similar during the years, in 1997 being only a few millimeters 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

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

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 the 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 mor-

tality (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 the 1970s (29). Until very recently, differences existed in socioeconomic status, morbidity, lifestyle, and risk behavior 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
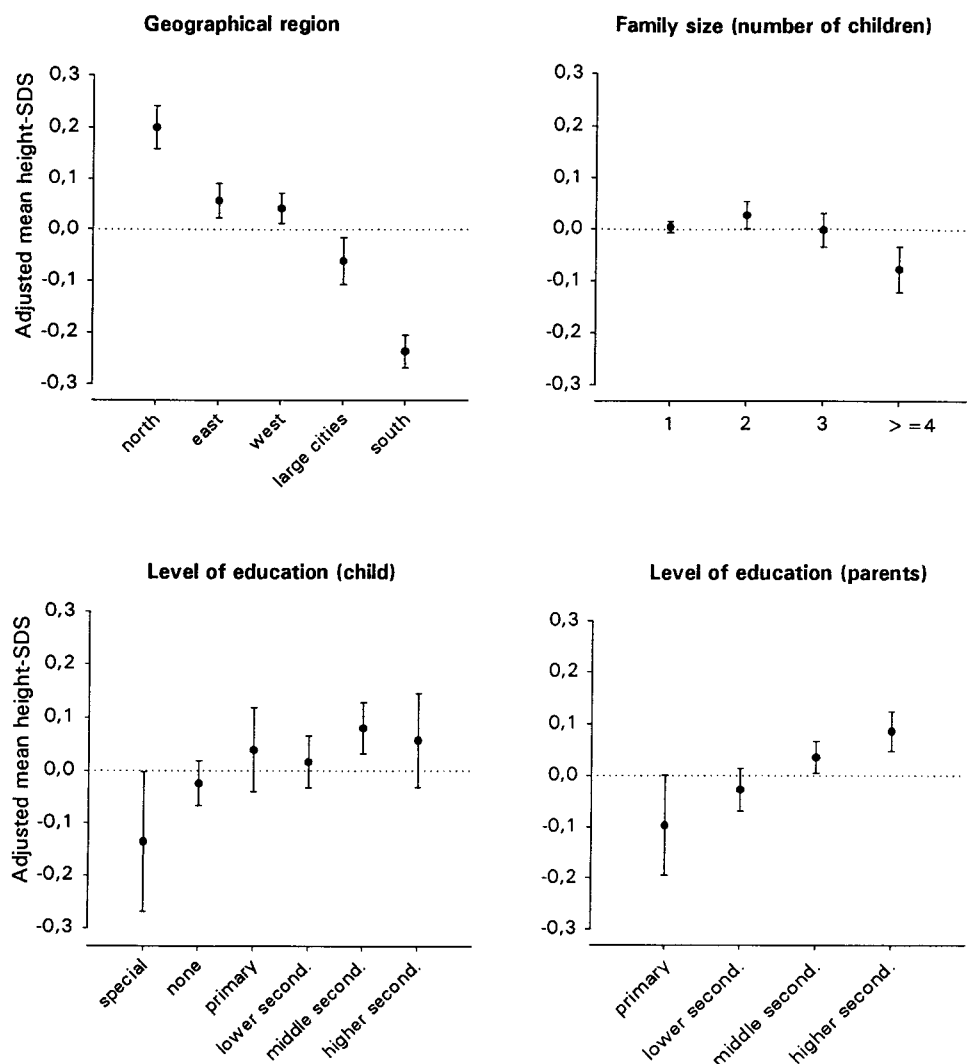
Geographical region

Family size (number of children)

Level of education (child)

Level of education (parents)

Figure 3. Mean height SDS (with 95% confidence intervals) for geographical region, family size, and level of education. Children, <5 y 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 of reaching the stages of secondary sex characteristics for boys and girls in the 1997 Dutch Growth Study

			Boys					Girls		
Characteristic		(y)	P_{10} (y)	P_{50} (y)	P_{90} (y)	Characteristic		P_{10} (y)	P_{50} (y)	P_{90} (y)
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
Testicular volume (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						

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 y are at least partially caused by 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 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 M continued to decrease during the past 42 y but at a slow rate. Although the socioeconomic conditions have been favorable for a number of decades, the positive secular change still continues.

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