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TARGET HEIGHT AND SECULAR TREND IN THE SWISS POPULATION

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INTRODUCTION

The following abbreviations are used throughout:

TH = Target Height
AH = Adult Height
MH = Mother's Height
FH = Father's Height
MPH = .5 x (MH + FH) = Midparent Height

All heights are given in centimeters.

In Tanner et al. (1970) the following formula for Target Height is recommended:

$$TH = MPH \begin{cases} (+\ 6.5 \text{ for boys} \\ (-\ 6.5 \text{ for girls} \end{cases} \qquad (1)$$

A 95 % confidence interval for the expected adult stature is then given, independent of sex, by TH +/- 8.5.

As shown below, this formula does not fit the Zürich data, the most important reason being that it does not take into account the secular trend but tends to reproduce - for an average difference between mothers and fathers of 13 cm - the average of the earlier generation.

Generally speaking, it is also somewhat questionable whether midparent height should go into the formula unmodified (coefficient 1.0). This is not to be expected, on the basis of simple additive genetic models, unless adult stature is completely genetically determined, i.e. not subject to environmental influences.

MATERIAL

244 children (125 boys, 119 girls) from the Zürich Longitudinal Growth Study (Prader et al., s.d.) were considered for this analysis. Almost without exception the mothers were measured in the hospital and by the same measurer who measured the children; this also applies to about 75 % of the fathers. About 20 % of the father's heights were measured at home by their wife, following the instructions of the above measurer. The quality of these measurements does not differ much from those taken in the hospital. A further 5 % were taken from Swiss army records (when the subjects were aged 19). The heights of the children correspond to their last measurement during the study.

7 children (5 boys, 2 girls) of tall stature and 3 more (2 boys, 1 girl) with developmental disorders were first eliminated. 15 more subjects (7 boys, 8 girls) were removed in a second step predominantly for statistical reasons (outliers, points with high influence on regression). The remaining 111 boys and 108 girls were then included in all computations.

BASIC UNIVARIATE RESULTS

No deviation from univariate normality could be detected. Accordingly, only a few simple statistics are given in tables 1 and 2 (parenthetical values refer to the original 244 sample).

Table 1: Basic statistics for children and parents in the Zürich Longitudinal Growth Study.

	AH		MH of			FH of		
	Boys	Girls	Boys	Girls	Pooled	Boys	Girls	Pooled
Mean	177.9	164.8	162.4	161.9	162.2	173.0	172.9	172.9
	(178.2)	(165.0)	(162.4)	(162.2)		(173.4)	(173.8)	
Standard deviation	6.1	5.4	5.1	6.2	5.7	5.9	6.1	6.0
	(6.7)	(5.9)	(5.5)	(6.7)		(6.7)	(7.2)	
Minimum	166.1	152.3	149.3	149.2		156.1	160.7	
Maximum	193.5	178.0	175.1	175.0		187.0	187.0	
Skewness*	1.34	.21	.33	.18		-1.24	-.38	
Curtosis*	-.63	-.54	-.98	-1.39		.37	-1.09	

* Skewness and curtosis standardized.

Table 2: Parent/offspring correlation for adult stature

	Boys AH	Girls AH	
MH	.36	.62	
FH	.44	.44	
MPH	.51	.67	
	MH	MH	Pooled
FH	.25	.27	.26

A few remarks are in order here (but see also 'Discussion' below):

a) while the average difference between parents' height is 10.7 cm, that between boys' and girls' height is 13.1 cm (table 1);

b) a first gross estimate of the secular trend is therefore 5.0 cm for boys and 2.6 cm for girls (table 1); and

c) the high correlation mother-daughter (table 2) is puzzling.

REGRESSION ANALYSIS

Tanner's formula (1) applied to the Zürich data yields the AH - TH distribution set out in Table 3. Approximately 80 % of boys and girls are underestimated - in the average by roughly 4 cm. The formula can be readily modified to eliminate bias by changing the constants as follows:

$$TH = MPH \begin{cases} (+\ 10.2 \text{ for boys} \\ (-\ \ 2.6 \text{ for girls} \end{cases} \qquad (2)$$

Table 3: Distribution of the residuals AH - TH (Tanner's formula)

	Mean	SD	Skewn. standardized	Curt. standardized	Min.	10%	50%	90%	Max.
Boys	3.7	5.4	-.56	-.76	-10.6	-4.0	3.8	10.3	16.8
Girls	3.9	4.2	-.90	-.54	- 6.6	-2.2	3.9	9.4	13.1

Accordingly, a 95 % confidence interval then emerges (Table 3) as TH +/- 10.8 cm for boys and TH +/- 8.4 cm for girls.
This formula is however not strictly optimal with regard to its predictive value.

Multiple linear regression is applied to the data. The regression equation under study will be of the form:

$$TH = a + b_1 \times MH + b_2 \times FH$$

Several questions immediately come to mind:

- are the coefficients of MH and FH both equal to 0.5 ?
- are the two coefficients equal, but not necessarily 0.5 ?
- are the equations for boys and girls the same, up to the constant ?
- is a linear regression model justified or are higher order terms indicated ?

With respect to the last question, a preliminary analysis showed that inclusion of higher order terms is not required. Analysis of variance Tables 4 and 5 provide separate answers for boys and girls to the preceding questions. Accordingly, F-tests for $b = b_2$ yield $F_{1,108} = 0.25$ for boys and $F_{1,105} = 4.6$ ($.01 < P < .05$) for girls. If we accept $b_1 = b_2$ then we can pool the sums of squares and obtain for the hypothesis $b_1 = b_2 = .5$ the F-values $F_{1,109} = 6.5$ ($P \approx .01$) for boys and $F_{1,106} = 11.9$ ($P \approx .001$) for girls.

We do not insist on the marginally significant 4.6 above, because it is not consistent over the sexes and is not confirmed by robust analysis (see also 'Discussion' below). Of greater interest is a test for equality among sexes of the residual standard deviations. A non-parametric Siegel-Tukey test yields a standardized value of 2.94 ($P \approx .0016$). With some caution, in view of this last result, we can pool more sums of squares and ask whether the same coefficient is justified for boys and girls. The corresponding F-test yields a very low value and we are led to the following formula, which we consider adequate:

$$TH = .718 \times MPH \begin{cases} (+\ 57.6 \text{ for boys} \\ (+\ 44.6 \text{ for girls} \end{cases} \qquad (3)$$

A 95 % confidence interval is then given by TH +/- 10.4 for boys and TH +/- 8.0 for girls.

DISCUSSION

The correlation daughter/mother is substantially higher than all other parent/offspring correlations. This high correlation is partially responsible for the higher precision of the prediction formula for girls, as well as for the high F-value in the test for

Table 4: ANOVA table for different regression models: boys

	SQ	DF	MS
$b_1 = b_2$	178.28	1	178.28
b_1 , b_2	6.79	1	6.79
Deviation from full model $TH=a+b_1xMH+b_2xFH$	2976.39	108	27.56
Deviation from smallest model $TH=a+.5xMH+.5xFH$	3161.46	110	

Table 5: ANOVA table for different regression models: girls

$b_1 = b_2$	192.25	1	192.25
b_1 , b_2	71.53	1	71.53
Deviation from full model $TH=a+b_1xMH+b_2xFH$	1639.78	105	15.62
Deviation from smallest model $TH=a+.5xMH+.5xFH$	1903.56	107	

equality of the coefficient of MH and FH. However, the hypothesis that all parent/offspring correlations are equal to 0.5, as well as the hypothesis that all these correlations are equal cannot be rejected at the 5 % level (chisquare or range test). A similar correlation pattern was observed by Welon and Bielicki (1971), but is not confirmed by other authors (quoted inter alia in Carter and Marshall, 1979). Should this effect be real, an exhaustive explanation would still be lacking.

Equation (3) yields a downwards adjustment for the average difference in stature between boys and girls from 13.1 (Table 1) to 12.9; this implies a correction for the secular trend from 5 to 4.9

cm for boys and from 2.6 to 2.7 for girls (as shown in Table 1, the parents of boys are, by chance, slightly taller than those of girls). This difference of 2.2 cm in the secular trend for boys and girls is significant at the 1 % level. It can be explained - but only in part - by an average age difference between fathers and mothers of 3 years and by some fathers being measured at a younger age (19 years). A similar difference was observed by Welon and Bielicki (1971).

It is noteworthy that formula (3), while significantly better ($P \approx .001$) than the corrected Tanner's formula (2), yields confidence intervals which are just a little narrower than those of the latter.

THE SECULAR TREND IN THE SWISS POPULATION

As indicated above, a secular trend is apparent among the children of the study, amounting to about 5 cm for boys and 3 cm for girls. This applies to children born around 1955, whose parents were born around 1925. No explanation can be given for this sex difference.

For the following, certain army records were consulted to study whether this trend had come to a stop. It is not appropriate in this context to examine this data in great detail. Bearing in mind the obvious fact that what follows applies only to boys (aged 19), we may summarize a few points;

a) the trend seems to have been relatively stable over the last 100 years, i.e. amounting to approximately 1 cm per decade (Fig. 1);

b) it has not come to a stop; if anything it seems to have been more important in the last few decades (1910-52, 1.2 cm/decade; 1952-62, 2 cm; 1962-72, 1.6 cm; 1972-77, 0.8 cm); and

c) with a few exceptions, there appears to be a catch-up effect in the sense that those cantons, whose boys were shortest, show a larger trend over the last two decades. Fig. 2 correlates the increments over the period 1957-77 with the achieved height in 1957. (This picture, however, inflates the negative correlation and should not be overemphasized).

Since these measurements were taken at age 19, we have no way of knowing whether the trend is wholly due to an increase in adult stature or, at least in part, to an earlier onset of pubertal development resulting in an earlier attainement of adult stature. Besides this, our data is insufficient at this time to allow a differentiation between further possible origins of an apparent trend in adult stature such as differential trends among social classes, changes in the population, etc.

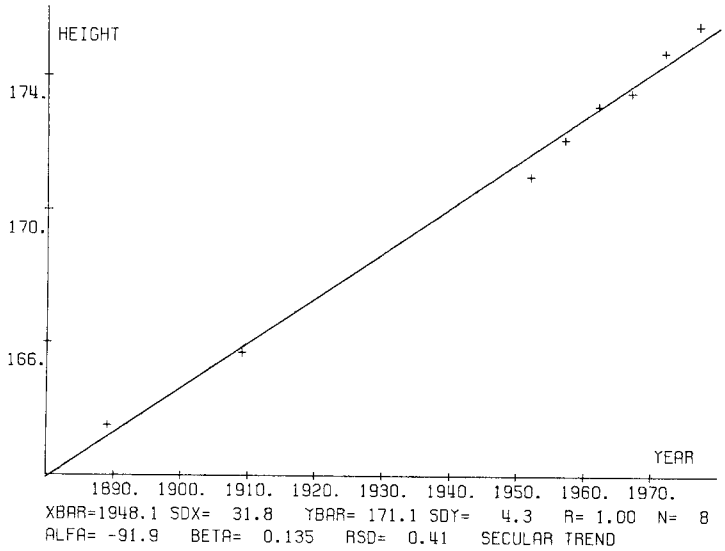

Fig. 1. Secular trend in stature in Swiss recruits 1890-1977

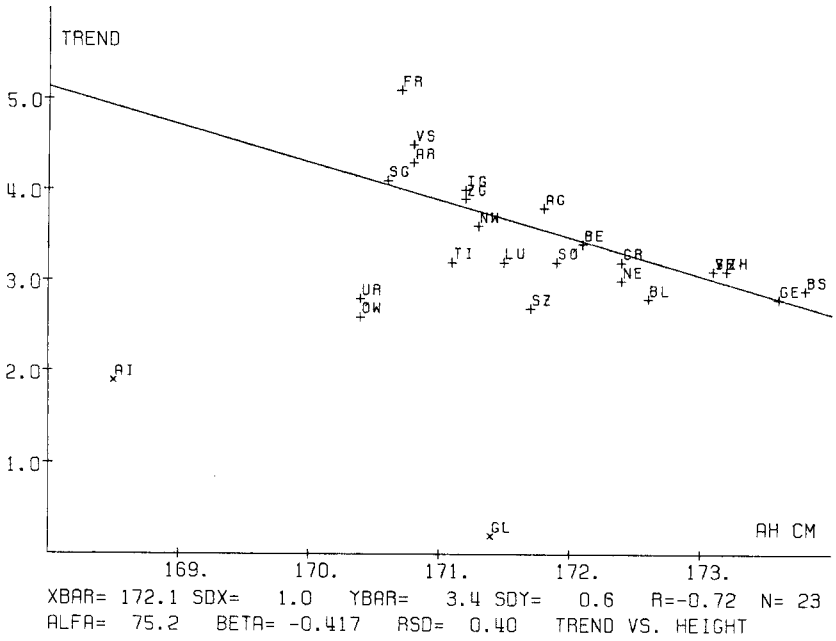

Fig. 2. Secular trend vs. achieved height in Swiss recruits, per canton, 1957-1977 (points AI and GL omitted in the computation of the regression line; other points weighted by the number of measurements)

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