Variability of Height, Weight, and Body Mass Index in a Swiss Armed Forces 2005 Census

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ABSTRACT The influence of the environment and genetics on individual biological characteristics, such as body mass and stature is well known. Many studies of these relationships have been based on conscript data. These studies often suffer from the fact that their data cover only a part of the population. Characterized by prosperity, democratic stability and enormous micro-regional cultural diversity, Switzerland is in the unique situation of offering data covering more than 80% of annual male birth cohorts. The aim of this study is to assess the impact of socioeconomic success, cultural differences, month of birth, and altitude (among other factors) on individual anthropometric characteristics of conscripts ($N \sim 28{,}000$) in the 2005 census. Our result highlights in such a large male sample the relationship between economic environment, regional cultural diversity, climate, and other factors, such as individual month of birth on stature and weight. Socioeconomic status, culture (as reflected by mother tongue), and month of birth were found to have significant effects on height and weight, while altitude did not show such effects. In general, weight is more affected by all these variables than height. Taking weight-dependent mortality and morbidity into account, it is of foremost public interest to know more about paired effects of living conditions on stature and weight in a highly developed society. Am J Phys Anthropol 137:457–468, 2008.

Anthropometric data—reflecting the morphology of the human body, its size, structure, form, and composition—help to assess the quality of life of a particular population. Values of biological characteristics of a human body depend on both endogenous-genetic and exogenous factors. The latter include socioeconomic factors, including cultural and political influences (psychological and physical stresses) that regulate direct biological inputs, e.g., diet (Wurm, 1982) and the effects of climate (Bergmann, 1847; Allen, 1877; Ruff et al., 1994). Even business cycles have been found to have an impact on individual stature (Weber et al., 1998; Woitek, 2003; Jacobs and Tassenaar, 2004; Brabec, 2005; Sunder and Woitek, 2005).

There is a body of literature on the interrelationship between stature and living standards (Bielicki and Welon, 1982; Cuff, 1994; Harris, 1994; Komlos, 1994; Steckel, 1995; Komlos and Cuff, 1998), with the focus of this literature being mostly on time trends of human stature and historic context (Malina, 1975; Bogin, 2001). Socioeconomic variables also influence the nutritional status of a particular population (Komlos, 1997): the higher the real *per capita* income, the easier the availability of food, both in terms of quantity and quality. This fact is crucial for optimal nutrition during childhood, since normal growth requires regular and high quality food intake (Baten, 1999). Individual stature thus depends not only upon genetic variation, but also on the nutritional and economic situation during periods important for individual growth. However, the link between socioeconomic status (SES) and anatomic-medical variables has not been fully explored so far (Baten, 1999).

Body height as a major anatomical feature has varied throughout hominid evolution (Frayer, 1984; Mathers and Henneberg, 1995; De Miguel and Henneberg, 1999). However, for the twentieth century of the Common Era, frequently described and often quite remarkable secular increases in stature of up to 150 mm (Van Wieringen, 1986) are not to be found everywhere. There are examples where there was no such increase, despite the fact that socioeconomic conditions improved (Henneberg and Van den Berg, 1990; Louw and Henneberg, 1997; Pretty et al., 1998). In addition, similar socioeconomic groups with the same stature show different averages of other anthropometric variables and physical performance, such as grip strength (Henneberg et al., 1998). The impact of socioeconomic factors and rural and urban background of individuals on the performance in functional tests (e.g., grip strength or reflexes) is known, yet not fully explained (Bielicki and Welon, 1982; Henneberg and Louw, 1998). Furthermore, since stature and morbidity and mortality are correlated (Hebert et al., 1993;

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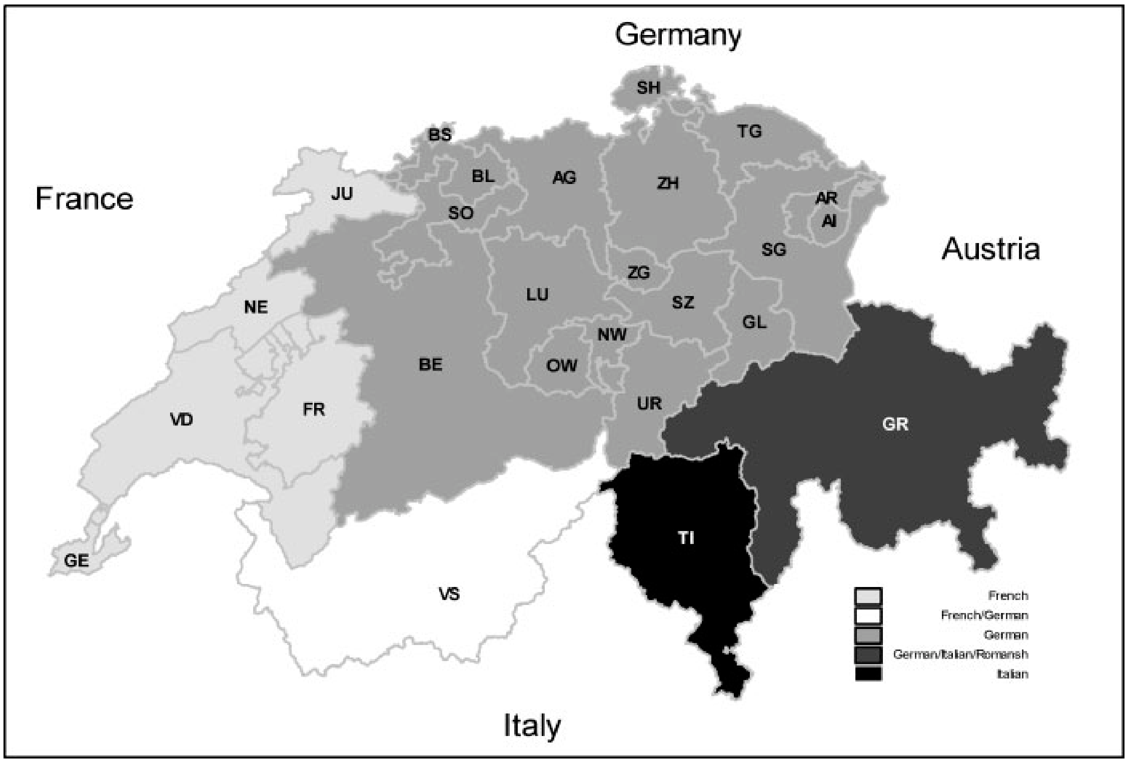

Fig. 1. Map of Switzerland showing the cantons with their native languages. Cantons: ZH, Zürich; BE, Bern; LU, Luzern; UR, Uri; SZ, Schwyz; OW, Obwalden; NW, Nidwalden; GL, Glarus; ZG, Zug; FR, Fribourg; SO, Solothurn; BS, Basel-Stadt; BL, Basel-Landschaft; SH, Schaffhausen; AR, Appenzell Ausserrhoden; AI, Appenzell Innerrhoden; SG, St. Gallen; GR, Graubünden; AG, Aargau; TG, Thurgau; TI, Ticino; VD, Vaud; VS, Valais; NE, Neuchâtel; GE, Genève; JU, Jura.

Engeland et al., 2003), it is of fundamental interest to explore further the link between environmental factors and biological living standards in modern societies based on reliable anthropometric data, such as those we present here. The term "biological standard of living" was coined by John Komlos (Komlos and Baten, 1998). It expands the measurement of well-being beyond the usual economic measures, such as the real wage or *per capita* income. The biological standard of living allows quantifying the impact of changes in the socioeconomic and epidemiological environment on the human body.

Some countries, such as Austria–Hungary, Poland, France, Sweden, Germany, the United States of America, Great Britain, Ireland, and Holland are quite well explored in terms of recent stature changes (Komlos, 1985; Sandberg and Steckel, 1987; Komlos, 1993; Weir, 1993; Komlos and Kriwiy, 2003; Komlos, 2003). Surprisingly, for Switzerland no recent anthropometric census data have been published so far. This is especially striking since Switzerland has a wealthy economy, which during the period 1900–1950 has reached the top gross domestic product *per capita* in Europe (Maddison, 2001). Thus, Switzerland through its armed forces data can serve as a unique model for anthropometric research due to multiple factors: First, Switzerland represents a well-developed egalitarian, and politically stable (federalist democracy) society. In addition, its small but diverse geography (ca. 300 × 150 km^2; lowlands and alpine regions of grossly different altitude and thus climate), as well as cultural diversity (e.g., four different native languages) allows for a variety of different comparisons. Switzerland consists of 26 cantons of different mother tongue, histories, economies, and level of urbanization (Fig. 1, Table 1). Finally, the Swiss armed forces are a draft army of all male citizens thus providing a large population cross-sectional sample.

The aim of this study is to explore the specific impact of possible etiological factors, such as regional culture or socioeconomic background on individual weight and height, based on the most recent census of the male population of Switzerland; a model country in terms of regional and social diversity. These data may serve as a baseline for further studies focusing on socio-medical implications of historic and recent anthropometric studies. First results on the interaction between metabolic parameters, such as blood cholesterol levels and anthropometric variables of this same sample have been explored recently showing a clear dependency of the two (Rühli et al., 2008).

MATERIALS AND METHODS

The newly introduced expanded recruitment concept of the Swiss Army, which is a draft army for male citizens, includes individual assessment of anthropometric data (e.g., measured height and weight), physical performance, voluntary metabolic tests, socioeconomic information (e.g., self-declared profession), and intelligence and psychological tests. Tests are taken under professional medical supervision at seven especially dedicated conscription centers located in various geographical parts of Switzerland with the identical qualitative standards for technical equipment and organizational structures as

TABLE 1. List of cantons with proportion of employees in the three main sectors

	1860			1985		
	Primary (%)	Secondary (%)	Tertiary (%)	Primary (%)	Secondary (%)	Tertiary (%)
ZH	34.4	**48.3**	17.3	3.7	30.7	**65.6**
BE	**42.7**	33.2	24.0	13.2	31.6	**55.2**
LU	**39.2**	30.5	30.3	14.2	33.6	**52.2**
UR	**46.8**	21.5	31.8	17.3	39.3	**43.4**
SZ	**54.8**	26.3	18.9	15.3	39.5	**45.2**
OW	**57.6**	24.1	18.3	20.7	33.5	**45.7**
NW	**53.9**	27.5	18.6	14.5	33.0	**52.5**
GL	22.0	**62.1**	16.0	11.3	**50.0**	38.7
ZG	**38.0**	36.9	25.1	6.0	38.1	**55.9**
FR	**56.2**	20.3	23.5	17.0	33.7	**49.3**
SO	**42.7**	34.6	22.7	7.2	46.1	**46.7**
BS	6.2	**55.3**	38.5	0.4	32.7	**66.9**
BL	30.8	**49.8**	19.4	5.5	45.7	**48.8**
SH	**43.4**	33.6	23.0	8.7	**46.8**	44.5
AR	15.9	**71.9**	12.2	14.9	37.5	**47.6**
AI	39.7	**45.0**	15.3	30.1	30.3	**39.7**
SG	36.9	**45.5**	17.6	9.4	42.3	**48.3**
GR	**62.2**	19.5	18.2	14.9	27.6	**57.5**
AG	**47.5**	35.6	16.9	8.6	45.1	**46.3**
TG	40.8	**41.2**	18.1	15.5	**45.3**	39.2
TI	**51.9**	30.0	18.1	4.8	36.1	**59.1**
VD	**47.4**	29.3	23.3	10.1	28.5	**61.4**
VS	**70.3**	13.0	16.7	20.5	29.3	**50.3**
NE	21.0	**53.9**	25.1	5.9	43.2	**50.9**
GE	9.1	**48.1**	42.8	1.9	22.0	**76.0**
JU				14.9	**45.2**	39.9

Sources: 1860: Swiss Economic and Social History Online Database, http://www.economic-history.uzh.ch/course/general.html, Tbl. F.10b; 1985: Federal Statistical Office, www.bfs.admin.ch, Tbl. 3.2.2.1.
Primary sector: agriculture; secondary: industrial production; tertiary: services; bold: biggest sector at particular time.
Cantons: ZH, Zürich; BE, Bern; LU, Luzern; UR, Uri; SZ, Schwyz; OW, Obwalden; NW, Nidwalden; GL, Glarus; ZG, Zug; FR, Fribourg; SO, Solothurn; BS, Basel-Stadt; BL, Basel-Landschaft; SH, Schaffhausen; AR, Appenzell Ausserrhoden; AI, Appenzell Innerrhoden; SG, St. Gallen; GR, Graubünden; AG, Aargau; TG, Thurgau; TI, Ticino; VD, Vaud; VS, Valais; NE, Neuchãtel; GE, Genève; JU, Jura.
Note: Canton JU has been established only as a separation from BE in 1979.

defined by Swiss Armed Forces Regulations developed since 1875 (*Nosologia militaria* No. 59.010; *Medizinische Beurteilung der Dientstauglichkeit und Dienstfähigkeit der Stellungspflichtigen und Angehörigen der Armee MBDD* No. 59.002).

About 28,512 male conscripts (for descriptive statistics, see Table 2) of the 2005 Armed Forces census (birth years 1984–1987) have been examined. They represent more than 80% of all 19-year-old male Swiss citizens alive in this year (Federal Statistical Office, FSO, www.statweb.admin.ch, Table BEV016A). Professions and vocations were grouped into main categories according to the *Berufsnomenklatur* 2000 classification of the FSO. To capture cultural influences, we used main language in the individual's municipality, and the impact of altitude as a climatic variable.

We analyze height, weight, and body mass index (BMI = weight[kg]/height[m]^2), which is a broadly used indicator for body shape, related to morbidity and mortality, and estimate the following model, using ordinary least squares:

$$y_j = \alpha_0 + \sum_{k=1}^{3} \beta_k \mathrm{AGE}_{jk} + \sum_{k=1}^{11} \gamma_k \mathrm{MONTH}_{jk} + \sum_{k=1}^{25} \delta_k \mathrm{CANTON}_{jk} + \sum_{k=1}^{2} \phi_k \mathrm{LANG}_{jk} + \sum_{k=1}^{11} \varphi_k \mathrm{OCC}_{jk} + \lambda \mathrm{ALT}_j + u_j; \quad j = 1, \ldots, 28512$$

where, AGE_{jk} is a dummy variable taking the value one if the conscript j is 18, 20, or 21 years-old (reference category: 19 years). The dummy variable MONTH_{jk} represents the month of birth of conscript j (reference category: April), CANTON_{jk} models the canton (reference category: Berne), The dummy variable LANG_{jk} indicates the main language in the district (reference category: German), and OCC_{jk} the occupation of conscript j, following the *Berufsnomenklatur* 2000 classification of the FSO (Agriculture, Engineering and IT, Construction and Mining, Trade, Services, Management and Administration, Health and Education, Students, Apprentices; reference category: Industrial Production). ALT_j represents the altitude of the district, and u_j is an error term following the usual assumptions. The reference categories were chosen based on the number of observations. Both, the dependent variable and altitude are in logs, which allow the parameter λ to be interpreted as elasticity (elasticity measures the percentage response of the dependent variable to a 1% change in an independent variable, see e.g., Pindyck and Rubinfeld, 1991). The parameters of the dummy variables are to be interpreted as percentage change with respect to the reference category, using the transformation exp(x)-1 (Goldberger, 1968; Halvorsen and Palmquist, 1980). The results of this exercise are displayed in Tables 3 and 4.

All individual data used in this study were fully made anonymous and were analyzed with programs written in Matlab®. No additional ethical approval is required for

TABLE 2. Descriptive statistics of the sample

		Height (mm)		Weight (kg)		BMI (kg/m^2)	
	N	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
ZH	3,977	1,782	66	73.1	12.3	23.0	3.5
BE	4,079	1,782	64	72.9	12.3	22.9	3.6
LU	1,804	1,785	63	73.0	12.1	22.9	3.5
UR	206	1,776	66	73.0	12.7	23.1	3.5
SZ	675	1,787	65	75.0	13.5	23.5	3.8
OW	216	1,769	57	72.6	12.7	23.2	3.6
NW	230	1,780	63	72.7	12.1	22.9	3.4
GL	186	1,775	67	71.5	9.9	22.7	3.1
ZG	436	1,788	64	73.0	12.2	22.8	3.3
FR	1,173	1,776	64	71.5	12.3	22.7	3.7
SO	949	1,777	63	72.0	11.7	22.8	3.2
BS	309	1,789	66	75.8	14.5	23.7	4.3
BL	932	1,784	67	74.5	13.4	23.4	3.9
SH	343	1,785	70	74.1	13.2	23.2	3.8
AR	309	1,780	62	71.8	11.6	22.6	3.2
AI	99	1,761	65	69.6	11.4	22.4	3.2
SG	2,269	1,779	65	71.9	12.3	22.7	3.6
GR	990	1,783	65	72.5	12.4	22.8	3.5
AG	2,169	1,780	67	73.2	12.3	23.1	3.4
TG	1,085	1,781	65	72.6	11.7	22.9	3.3
TI	1,147	1,776	63	71.6	12.4	22.7	3.5
VD	1,723	1,783	64	71.7	12.0	22.5	3.4
VS	1,311	1,777	64	71.4	12.9	22.6	3.7
NE	781	1,776	63	71.2	12.4	22.6	3.6
GE	769	1,774	65	70.4	11.1	22.4	3.4
JU	345	1,781	69	71.5	11.2	22.5	3.2
Total	28,512	1,781	65	72.6	12.3	22.9	3.5

For abbreviations of cantons see Table 1.

TABLE 3. Influence of age (with largest subgroup as reference) on individual height, weight, and BMI (bold: significant at P *< 0.05)*

			Height (Log)		Weight (Log)		BMI (Log)	
		N	Parameter	*P*-Value	Parameter	*P*-Value	Parameter	*P*-Value
Age (reference category: 19 years)	18	1,046	−0.002	0.076	−0.009	0.097	−0.004	0.345
	20	10,551	−0.001	0.053	**0.011**	**0.000**	**0.013**	**0.000**
	21	3,557	**−0.003**	**0.000**	**0.013**	**0.000**	**0.018**	**0.000**

anonymized Swiss governmental statistical data (Swiss data privacy act, SR 235.1; 19.6.1992).

RESULTS

Geographic patterns

There is significant variation among cantons in height, weight, and BMI (Table 2). In terms of average stature, there is a maximum difference of 28 mm between the means for various cantons (Table 2, Fig. 2). The cantons with the tallest average conscripts are located in central and eastern Switzerland, all German speaking areas. By contrast, the Italian speaking canton of Tessin shows one of the lowest average statures.

The average weights and body mass indices among the cantons show a different pattern (Table 2, Fig. 3). High average body mass indices can be found in the central and north-western parts of Switzerland, whereas the southern mountainous and western cantons are below average.

The geographic pattern of BMI is very similar to the one of body weight, again showing an increase from the French-speaking cantons towards the German speaking cantons. This is also true, if one focuses only on the individuals with a BMI of more than 30 kg/m^2, which is the cut-off point set by the WHO for pathological obesity (Fig. 4). A total of about 4% of all Swiss conscripts show such an elevated BMI with urban cantons prevailing.

Weight shows a much higher regional coefficient of variation (calculated based on cantonal means) than height, and so does BMI (Fig. 5).

Age-dependent variation

Individual age influences height negatively only for the oldest age group of 21-year-olds, whereas weight and BMI both increase significantly in the 20 and 21-year-old age group, in comparison to the largest reference group of the 19-year-old conscripts (Table 3). To illustrate the interpretation of the parameter values, consider the average weight of 72.1 kg for the 19 years-old. The model predicts that the difference to the 18 years-old is insignificant, while weight increases by 1.11% (exp(0.011)-1) for the 20 years-old and by 1.31%

TABLE 4. Possible influencing factors (with largest subgroup as reference) for individual height, weight, and BMI (bold: significant at P *< 0.05)*

		Height (Log)		Weight (Log)		BMI (Log)	
	N	Parameter	*P*-Value	Parameter	*P*-Value	Parameter	*P*-Value
Month of birth (reference category: April)							
January	2,463	−0.001	0.146	0.000	0.936	0.003	0.513
February	2,312	−0.001	0.376	0.003	0.548	0.005	0.262
March	2,450	0.000	0.814	0.003	0.482	0.004	0.366
May	2,494	0.000	0.864	−0.002	0.729	−0.001	0.765
June	2,411	0.000	0.860	−0.004	0.373	−0.004	0.279
July	2,502	0.001	0.392	−0.005	0.275	−0.007	0.098
August	2,373	**−0.002**	**0.026**	**−0.012**	**0.009**	−0.007	0.075
September	2,495	−0.001	0.447	−0.005	0.243	−0.004	0.361
October	2,297	**−0.003**	**0.009**	**−0.011**	**0.021**	−0.005	0.216
November	2,113	−0.001	0.297	**−0.015**	**0.001**	**−0.013**	**0.002**
December	2,086	−0.002	0.106	**−0.013**	**0.005**	**−0.010**	**0.022**
Canton (reference category: BE)							
ZH	3,977	−0.001	0.435	0.006	0.121	**0.007**	**0.033**
LU	1,804	0.001	0.420	0.004	0.333	0.003	0.505
UR	206	−0.004	0.123	0.003	0.791	0.011	0.278
SZ	675	0.002	0.110	**0.026**	**0.000**	**0.021**	**0.000**
OW	216	**−0.007**	**0.008**	−0.004	0.689	0.009	0.358
NW	230	−0.001	0.554	−0.001	0.924	0.002	0.844
GL	186	−0.004	0.160	−0.018	0.130	−0.010	0.332
ZG	436	0.002	0.282	0.006	0.428	0.002	0.739
FR	1,173	−0.001	0.480	0.000	0.975	0.002	0.691
SO	949	**−0.003**	**0.013**	−0.011	0.063	−0.004	0.423
BS	309	0.002	0.454	**0.047**	**0.000**	**0.043**	**0.000**
BL	932	0.001	0.555	**0.023**	**0.000**	**0.021**	**0.000**
SH	343	0.001	0.591	**0.020**	**0.028**	**0.018**	**0.030**
AR	309	−0.002	0.378	−0.016	0.081	−0.013	0.136
AI	99	**−0.013**	**0.001**	**−0.044**	**0.007**	−0.018	0.203
SG	2,269	**−0.003**	**0.006**	**−0.011**	**0.009**	−0.006	0.129
GR	990	0.000	0.766	−0.007	0.229	−0.008	0.136
AG	2,169	−0.001	0.152	0.005	0.250	**0.008**	**0.044**
TG	1,085	−0.001	0.461	−0.002	0.653	−0.001	0.901
TI	1,147	**0.012**	**0.020**	−0.013	0.565	−0.036	0.067
VD	1,723	**0.004**	**0.011**	0.011	0.109	0.003	0.626
VS	1,311	−0.001	0.655	−0.001	0.885	0.000	0.946
NE	781	−0.001	0.486	0.009	0.280	0.012	0.118
GE	769	−0.004	0.061	0.004	0.615	0.011	0.129
JU	345	0.002	0.357	0.011	0.277	0.007	0.458
Language (reference category: German)							
French	5,769	**−0.005**	**0.001**	**−0.025**	**0.000**	**−0.016**	**0.003**
Italian	1,206	**−0.018**	**0.000**	0.008	0.703	**0.043**	**0.023**
Occupation (reference category: Industrial production)							
Missing	496	**0.005**	**0.002**	−0.003	0.667	**−0.014**	**0.037**
Agriculture (1)	1,214	0.000	0.778	**0.015**	**0.002**	**0.014**	**0.001**
Engineering, information technology (2)	2,011	**0.004**	**0.000**	−0.007	0.074	**−0.016**	**0.000**
Construction and mining (2)	2,419	**−0.002**	**0.007**	**0.007**	**0.045**	**0.012**	**0.000**
Trade (3)	3,409	0.001	0.210	−0.006	0.060	**−0.008**	**0.006**
Services	917	**−0.003**	**0.015**	−0.007	0.184	−0.001	0.810
Management/administration (3)	186	−0.004	0.109	**−0.039**	**0.001**	**−0.030**	**0.004**
Health and education (3)	347	0.001	0.530	**−0.022**	**0.010**	**−0.025**	**0.001**
Unspecified	1,662	−0.001	0.512	−0.008	0.076	−0.006	0.101
Students	7,516	**0.006**	**0.000**	**−0.020**	**0.000**	**−0.031**	**0.000**
Apprentices	104	**−0.007**	**0.065**	**−0.044**	**0.005**	**−0.030**	**0.031**
Altitude (log)		0.000	0.875	0.006	0.167	0.005	0.144

For abbreviations of cantons see Table 1.
(1) Primary, (2) Secondary, (3) Tertiary sector.
To illustrate the interpretation of the parameters, e.g., the variation among cantons in height, consider the average height of 178.1 cm (Table 2). The model predicts, e.g., that the difference between canton Bern (reference canton) and canton Obwalden is significant, thus being 0.7%, which equals 1.2 cm on average.

(exp(0.013)-1) for the 21 years-old, an increase by 0.79 and 0.94 kg, respectively.

Other environmental variables

The average individual height and weight differs by month of birth of conscripts (Fig. 6). Generally, weight is more often significantly influenced by month of birth than height (Table 4). In particular, conscripts who were born in the second half of the year show significantly lower average weights and also lower average height and BMI (Fig. 6; Table 4).

The largest occupational grouping of conscripts working in the industrial sector shows lowered height and

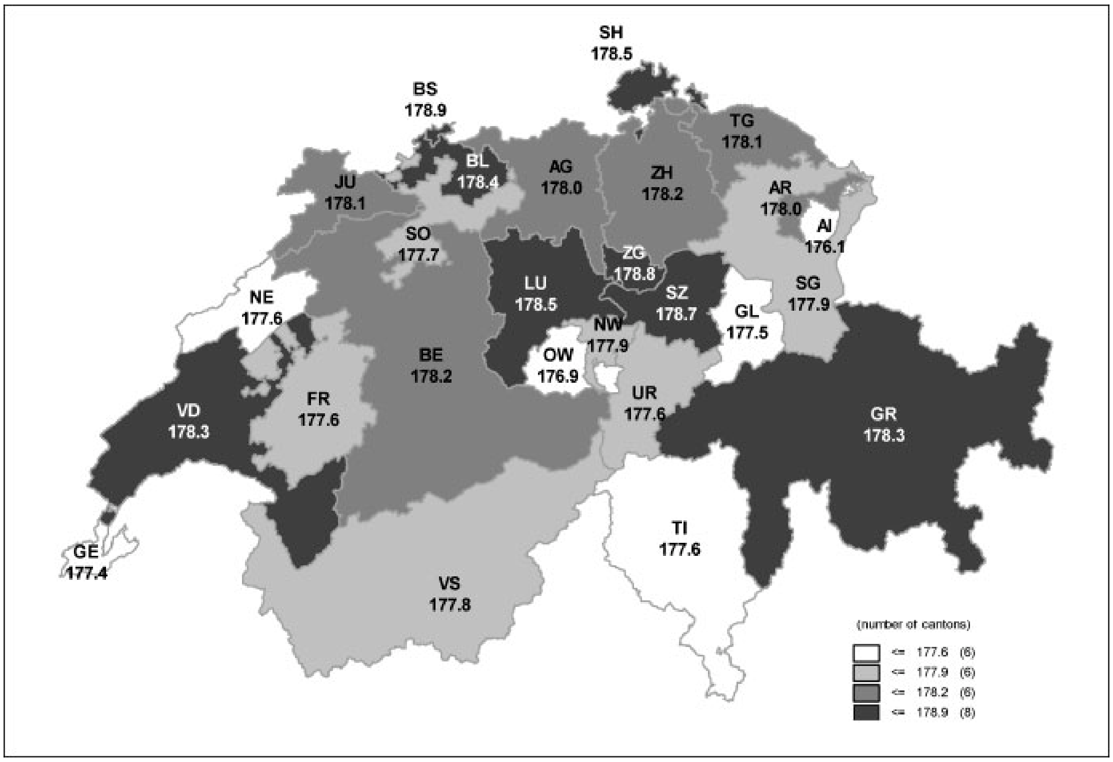

Fig. 2. Average individual height of conscripts by canton. Cantons-Abbreviations see Figure 1.

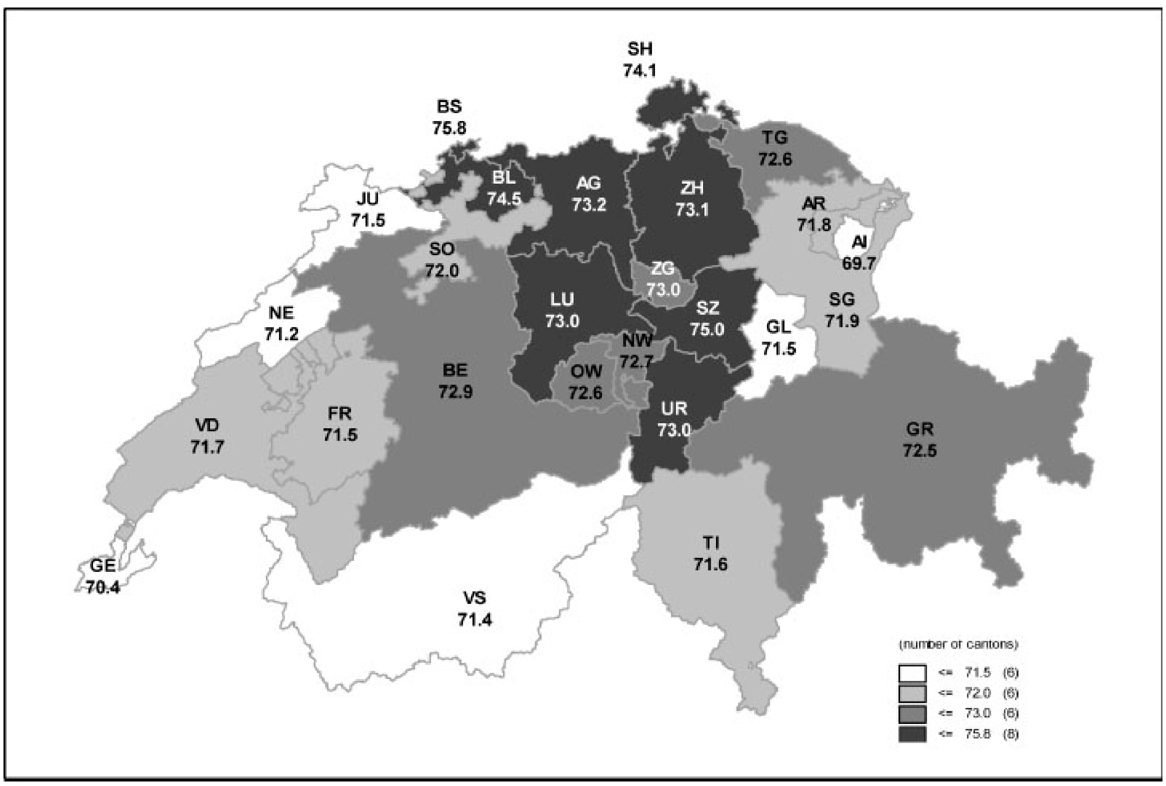

Fig. 3. Average individual weight of conscripts by canton. Cantons-Abbreviations see Figure 1.

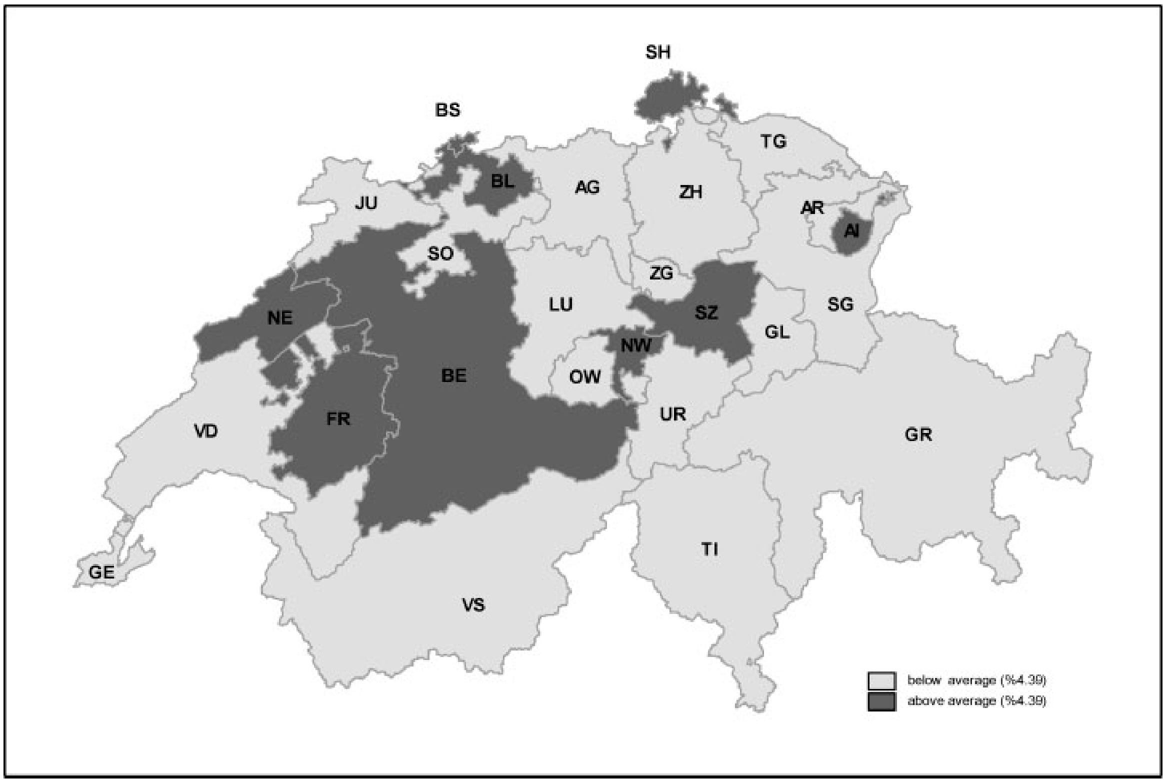

Fig. 4. Cantons with higher or lower than average proportion of conscripts with a BMI above 30 kg/m^2 (defined as obesity). Cantons-Abbreviations see Figure 1.

increased weight in comparison to other occupational groups, especially university students (Table 4). BMI values reflect the same trend.

Average altitude of conscripts' canton of residence does not show any significant impact on individual height, weight or BMI (Table 4).

Secular trend of stature

To give an impression of the secular trend in stature, we compare our data with the oldest available published data set for Swiss conscripts (birth years 1865–1872, *Aerztliche Rekrutenuntersuchungen*, *Schweizerische Statistik*, L62, L65, L68, L72, L77, L81, L85, L96.). The mean heights displayed in Figure 7 show that regionally diverse patterns of average statures of Swiss conscript cohorts can be found for both the birth years 1865–1872 and 1984–1987 (Fig. 7). For example, the conscripts of Canton *Appenzell-Innerrhoden* are prominently shorter than the Swiss mean for both birth cohorts. Conscripts born in 1865–1872 from Canton *Geneva*, by contrast, are almost 3 cm taller than average, although this difference decreases with time.

Also clearly visible is the general increase of stature by almost 15 cm within ca 120 years. Furthermore, the Swiss-wide increase in stature is accompanied by a decrease of cantonal variance (coefficient of variation of 0.01 vs. 0.003 for the 1865–1872 vs. 1984–1987 samples, respectively). Even a canton with a high rate of people currently working in the secondary sector, e.g., *Schaffhausen,* shows these general trends within about 100 years (Fig. 8, Table 1).

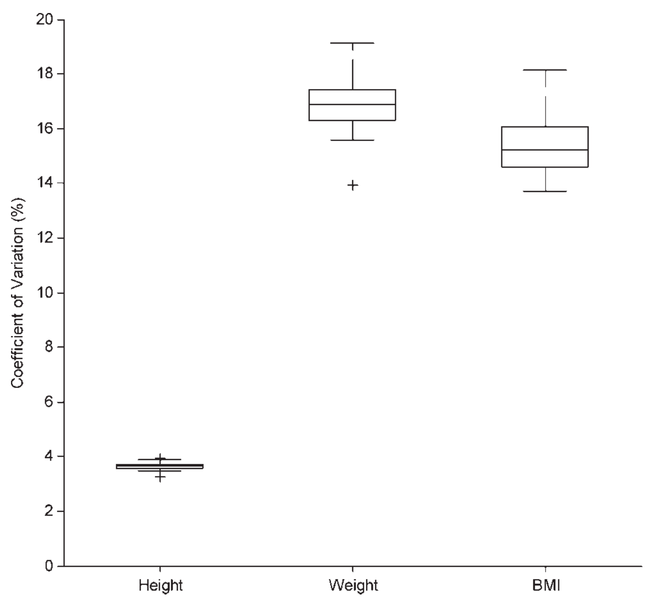

Fig. 5. Coefficient of variation among cantons for average height, weight, and BMI of conscripts.

DISCUSSION

Anthropometric surveys have a long scientific tradition, and changes in human stature and BMI are widely discussed phenomena. For example, a possible correla-

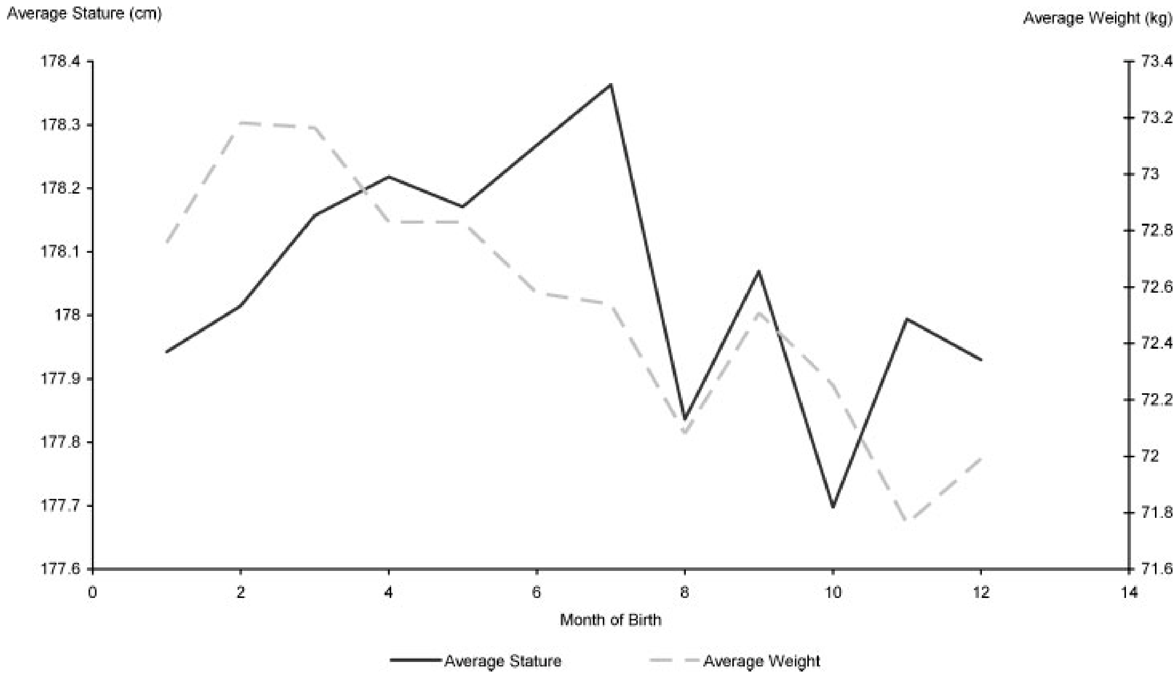

Fig. 6. Absolute average height and weight of conscripts by month of birth.

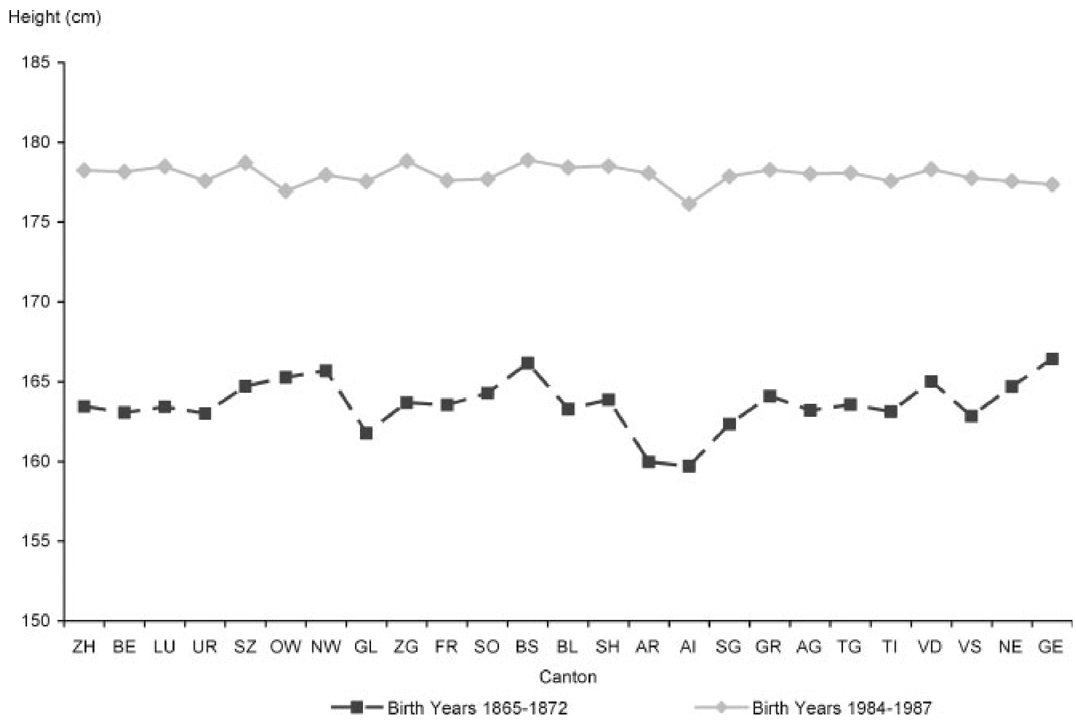

Fig. 7. Average height of conscripts of birth years 1865–1872 and 1984–1987 by canton. Cantons-Abbreviations see Figure 1. *N* (for birth years 1865–1872; *N* for cohort 1984–1987, see Table 2): ZH 20,288; BE 37,202; LU 8,888; UR 1,213; SZ 3,385; OW 942; NW 735; GL 1,819; ZG 1,562; FR 8,145; SO 6,246; BS 3,814; BL 3,824; SH 2,099; AR 2,981; AI 776; SG 14,193; GR 5,209; AG 12,121; TG 6,248; TI 4,705; VD 17,043; VS 6,504; NE 8,021; GE 4,190.

tion of individual stature morbidity and mortality risk has been addressed in studies of military personnel (Okamoto et al., 2001; Linares and Su, 2005). We are able to present a unique sample of male conscripts of a draft army to assess major anthropometric data, such as individual weight and height.

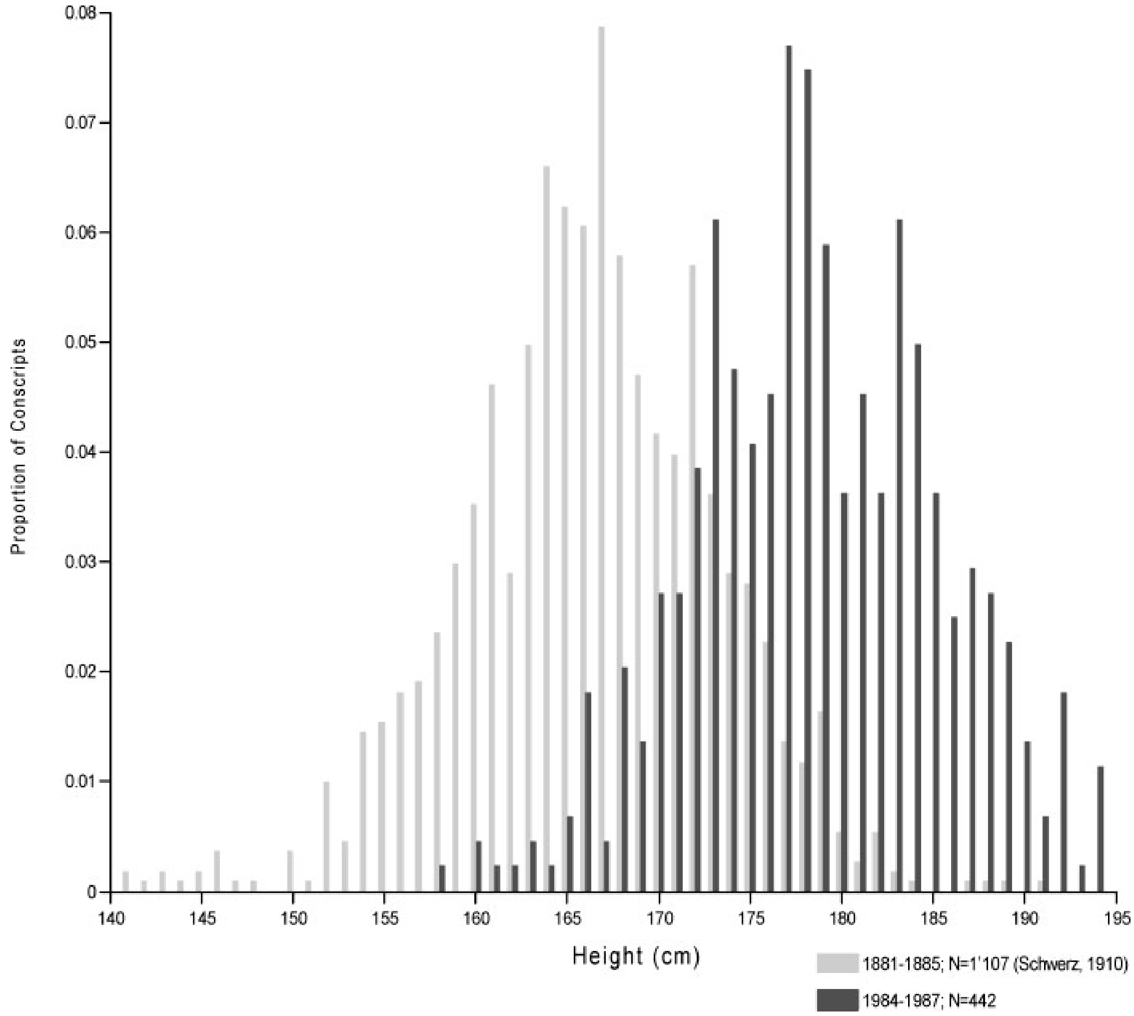

Fig. 8. Secular trend in stature in the exemplary canton of *Schaffhausen*; birth years 1881–1885 (light grey; N = 1,108; Schwerz, 1910) and 1984–1987 (dark grey; N = 443).

Secular trends of height and weight in the last century are well known. We find that average stature in Switzerland increased by about 100 mm within one century, with some cantonal variation due to alterations of the general trend towards urbanization, as reflected in a major rate shift from the primary towards the tertiary sector (Table 1, Fig. 9). Average height of Swiss conscripts increased, from about 1,690 mm (Theiler, 1927) in 1916 to about 1,780 mm in 2005. Today, average height of Swiss conscripts is comparable to that of White US males or South Africans of European extraction (Henneberg and Van den Berg, 1990; Komlos and Lauderdale, 2007). This may be due to improvements in health care and greater availability of food that relaxed adaptive pressures for more energetically efficient smaller bodies (Frayer, 1981; Frayer, 1984; Henneberg and Steyn, 1995).

We detected greater regional (cantonal) differences in body weight than in height. This indicates that the general level of socioeconomic development in Switzerland limits regional differences in stature. Nevertheless, the fact that weights vary between cantons may represent a side-effect of "luxury" and may be linked with culturally affected nutritional habits. This is consistent with earlier work by us on the regional variation of individual total cholesterol blood levels in the same sample showing, e.g., higher cholesterol values in the French speaking part (Rühli et al., 2008). The importance of regionally well described samples, such as the present Swiss one can also be highlighted by historic data. For two Swiss regions—only about 30 km apart—the average increase in stature from 1885 to 1910 varied from +2 to +59 mm, respectively (Pittard and Dellenbach, 1931). This variation in the amount of changes is also seen in the fact that there is no significant correlation (r = 0.356, df = 23) between average statures per canton measured in 1865–1872 and in 2005 (data from Fig. 7), that is the regional pattern of average statures has changed over some 140 years (Fig. 9). In our modern samples regional stature differences are generally smaller than in the 19th century (Fig. 7), possibly due to an underlying increase in mobility and thus genetic exchange or an increasing homogeneity of environment, or even a combination of the two. The general secular increase in mobility of the Swiss population can be clearly seen in Table 5.

Individual height and weight is influenced by SES, a phenomenon well described in the literature and also found in our sample. However, in our cross-sectional data set, weight is more prominently affected by SES than height. This is again an indicator—similar to the trend found in the regional coefficient of variation—that in a society, such as in Switzerland, height is becoming less dependent than weight on extrinsic factors, such as nutritional habits. Also, since social inequality declines the variance in height also declines. Often, in such societies, body weight has a greater part of its variation

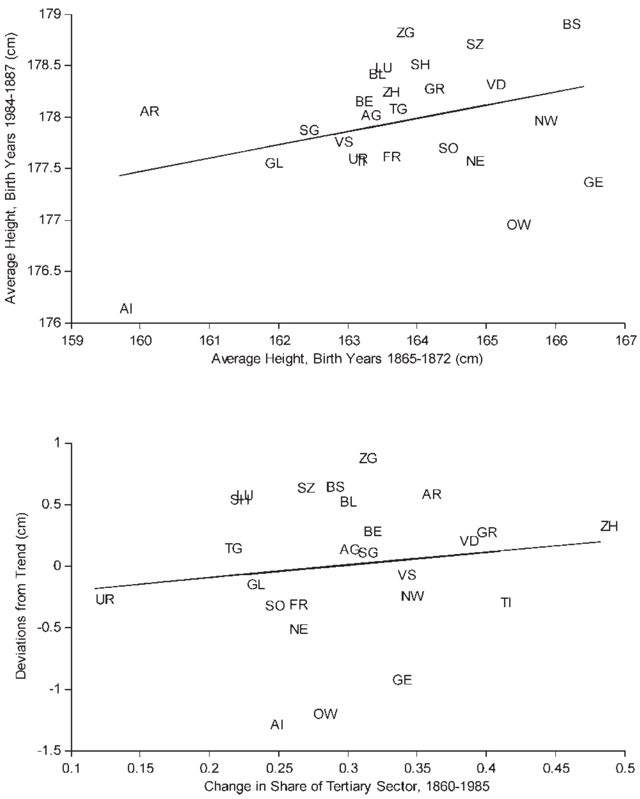

Fig. 9. Average height of conscripts of birth years 1865–1872 and 1984–1987 by canton. In the upper graph, average height of conscripts born 1984–1987 is plotted against average height of conscripts born 1865–1872. The lower graph contains a plot of the residuals of the regression in the upper graph against the change in the share of the tertiary sector (1860–1985) as a measure for economic development. Cantons-Abbreviations see Figure 1. *N* (for birth years 1865–1872; *N* for cohort 1984–1987, see Table 2): ZH 20,288; BE 37,202; LU 8,888; UR 1,213; SZ 3,385; OW 942; NW 735; GL 1,819; ZG 1,562; FR 8,145; SO 6,246; BS 3,814; BL 3,824; SH 2,099; AR 2,981; AI 776; SG 14,193; GR 5,209; AG 12,121; TG 6,248; TI 4,705; VD 17,043; VS 6,504; NE 8,021; GE 4,190.

influenced by environmental factors, e.g., 36% in Belgium (Susanne, 1971), than does body height—less than 1% in Belgium (Susanne, 1971) or just 8% in Poland (Sklad, 1973). Body height responds poorly to improvements in living conditions in such countries as, e.g., Australia or South Africa (Henneberg and van den Berg, 1990; Henneberg, 2001) while body weight there is still increasing in the 21 century (Henneberg and Veitch, 2003, 2005). The specific exploration of possible underlying SES-based etiologies, such as regional business cycles in historical Swiss male statures is part of another study (Rühli and Woitek, in preparation).

Surprisingly, we found a clear influence of month of birth on adult weight for more months than stature. Earlier reports already claimed such an influence of individual month of birth on stature and weight (Henneberg and Louw, 1990; Henneberg and Louw, 1993), but in Central European conscript data only an effect on height was found (Weber et al., 1998) A clear explanation of this phenomenon is lacking and may need further investigations, especially if one wants to study the etiology of the well-described increase in average body weight in most modern societies.

The influence of altitude may consist of two components with opposing effects on human body size and shape. The first effect is that of temperature, which will produce changes described by Allen's and Bergmann's rules (Bergmann, 1847; Allen, 1877; Jacobs, 1985). The second is decreasing atmospheric pressure, which may result in hypoxia limiting physical growth, particularly linear growth, and development (Greksa, 2006). While lower temperatures favor increased body weight, hypoxia may produce smaller bodies thus confounding effects of temperature. Astonishingly, we found no significant impact of altitude on either height or weight, and thus also not on BMI. It may be a result of opposite influences of temperature and hypoxia, but also it may indicate that the range of altitudes in Switzerland (280–1,430 m above sea level), much smaller than, e.g. in the Andes, is too narrow to produce distinguishable effects.

Data obtained by large survey studies, such as ours are important to the design of future public health policies. For example, we found that young adult males—in a society such as in Switzerland—still vary in individual height and body weight by minor differences in SES or regional background. They may also vary in individual morbidity and mortality risk. The early detection of these risks should prompt more specific target-group oriented preventive measures and, thereby, prevent or at least delay more serious health complications, such as stroke or myocardial infarction. Thus, society as a whole, and public health programs in particular, will benefit from such anthropometric information on possible groups at risk.

TABLE 5. Percentage of population (census years 1910 and 1990) by place of birth

	Year	Born in current district	Born in same canton, but different district	Born in same canton	Born in another canton	Born in Switzerland	Born in foreign country
Male	1910	50	23	72	15	87	13
	1990	33	24	57	21	78	21
Female	1910	47	26	73	16	89	11
	1990	27	27	54	25	79	20

Source: Table B17, Swiss Economic and Social History Online Data Base; http://www.fsw.unizh.ch/histstat/nls/

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